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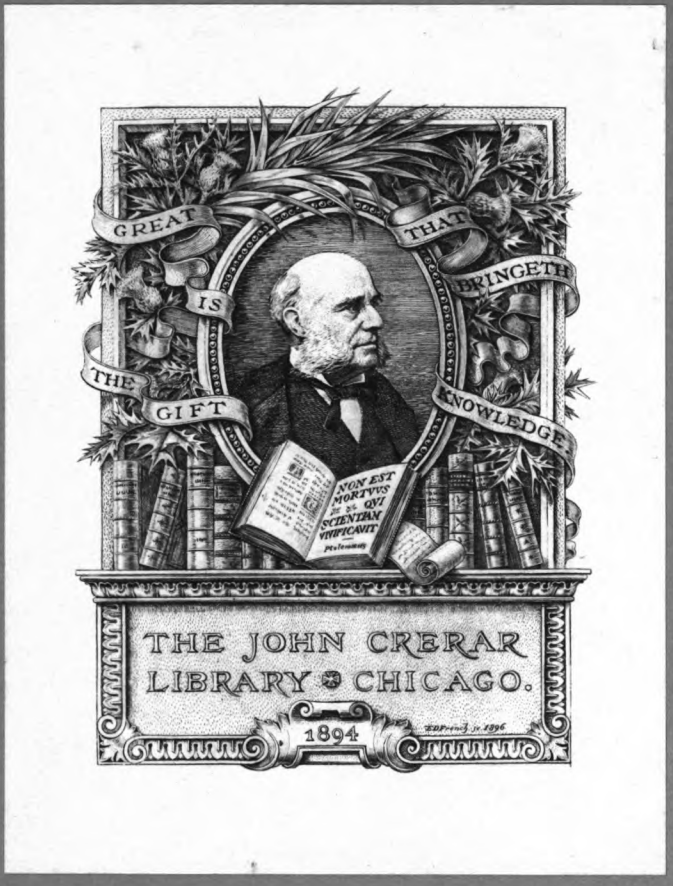
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NEW SERIES 1912 NO. 1

Transactions

of the

New York Electrical Society

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The Chemistry of Tungsten, and the Evolution of the Tungsten Lamp

BY

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Professor of Chemistry and Director of Laboratories, College of City of New York

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Radio Engineering at the College of the City of New York

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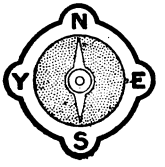

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TRANSACTIONS

OF THE

New York Electrical Society

NEW SERIES 1912 NO. 1

THE CHEMISTRY OF TUNGSTEN AND THE EVOLUTION OF THE TUNGSTEN LAMP.*

Charles Baskerville, Ph. D., F. S. D., Professor of Chemistry and Director of Laboratories, College of the City of New York.

In 1781, Scheele found that the mineral "tungstein," now termed scheelite, was not a tin ore, as had been supposed, but contained a new, peculiar acid which he named tungstic acid. Two years later Juan José and Don Fausto de Elhuyar showed that wolframite contained the same acid, the properties of which they studied. The principal points in the history of tungsten may be thus summarized:—

1758—Cronstedt suspected the presence of an unknown earth in cassiterite (tin dioxide).

1779—Woulfe observed that the action of an acid on pulverized "tungstein" gave a characteristic yellow color, and he was unable to offer a satisfactory explanation.

1781—The discovery by Scheele.

1783—The analysis of wolframite by the brothers de Elhuyar, who found that it contained iron, manganese and tungsten.

1815—The discovery of the alloy with iron by Hassenfratz.

1824—The production of tungsten bronze by Wöhler.

1826—The determination of the atomic weight by Berzelius, who reported the value 189.324.

1834—The preparation of alloys of iron and tungsten by Berthier.

* A lecture delivered at the 313th meeting of the New York Electrical Society, October 29, 1912, in the Doremus Lecture Theatre of the Chemistry Building of The College of the City of New York.

In delivering this lecture, which was profusely illustrated, Dr. Baskerville spoke from notes only. Owing to the requests of a number of the members of the Society, he prepared the above paper, which deals as closely as possible and in much the same style, with those subjects discussed in the lecture. The United States statistics have been revised to include 1912.

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1836—The reduction of tungsten trioxide to the blue oxide by Malaguti.
1848—The technical preparation of sodium tungstate by Oxland.
1857—Employment in fire-proofing by Versmann and Oppenheim.
1868—Use of a 5 per cent. tungsten steel for rails in Terre Noire.
1882—The invention of tungsten shot for military purposes by Meig and Bischoff.
1887—The invention of the tungsten filament lamp by Turner D. Bottome.
1893—Recovery of an 80 per cent. ferro-tungsten in the works of the Biermann-Metallindustrie.
1903—The invention of the Just lamp.
1905—The invention of the Kŭzel lamp.
1911—The production of ductile tungsten. The new "Mazda" lamp.

THE PRODUCTION OF TUNGSTEN ORES.

The quantity of tungsten ore mined and marketed in the United States in 1912 was equivalent to about 1,290 tons, averaging 60 per cent. of tungsten trioxide, in addition to which a smaller quantity was mined but not marketed. The average price per unit was about $6.35 in 1912, $8.00 being quoted at the end of the year. The output of concentrated tungsten ore by the leading producing countries for the three preceding years, in metric tons, is shown in the accompanying table.

TABLE I.—OUTPUT OF CONCENTRATED TUNGSTEN ORE.

Country	1909	1910	1911
Argentina	817	1,912	—
Australasia—New South Wales	325	321	398
Queensland	617	873	553
Tasmania	29	68	71
New Zealand	79	179	140
Austria	39	40	—
Bolivia	152	210	—
Burma	—	—	1,094
England	382	274	266
France	54	30	—
Germany (Saxony)	96	95	—
Portugal	673	943	1,000
Spain	129	153	—
United States	1,469	1,833	1,173

The largest production in 1912 came from Boulder County, Colo., where the Primos Mining & Milling Co. and the Wolf

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Tongue Mining Co. were the principal producers. The ore mined in the Boulder district is mainly ferberite (iron tungstate), not obtainable in large quantity at any other place in the world, although the other two iron-manganese tungstates, hübnerite and wolframite, as well as calcium tungstate (scheelite) are also found in this field.

The milling practice in the Boulder district is essentially as follows: In breaking the ore at the mine, the highest grade is sorted and then shipped without any preliminary milling; this grade must average at least 40 per cent. tungstic acid. The lower grades, ranging from 3 per cent. to 15 per cent. tungstic acid, are concentrated by wet methods. Two grades of concentrates are recovered and shipped; the first contains 60 per cent. or more tungstic acid, the second from 35 to 40 per cent. The former is usually recovered as coarse concentrate and the latter as slime.

In 1912, The Atolia Mining Co., which controls the Atolia field, at the north edge of San Bernardino County, Cal., was the largest individual producer of tungsten ore in this country. The usual run is about 40 tons of 65-67 per cent. concentrates per month. Small operations were also conducted during the year in Arizona, Nevada, Idaho, New Mexico, and Washington.

With regard to the foreign production, it may be noted that the output of tungsten ore concentrates in Portugal amounts to something over 1,000 metric tons per year. It is said that the mines could increase their output sufficiently to supply the present demand of all Europe. At the present time, the Portugal ores, which are remarkable for their purity, are largely used by the French electrometallurgical plants.

GEOCHEMICAL CONSIDERATIONS.

The tungsten minerals serving as ores are hübnerite, a tungstate of manganese; wolframite, a tungstate of manganese and iron; ferberite, a tungstate of iron; and scheelite, a tungstate of calcium. The first three minerals grade into each other; hence, wolframite is used as a class name. The tungsten minerals, like tin ore, generally occur in veins cutting igneous rocks containing much silica, such as granite and granodiorite. Hence, in general,

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search for tungsten may be expected to be most successful in districts of granitic rocks. Apparent exceptions to this rule are, so far as I am aware, only at Nome, Alaska, where scheelite is found in the gold placers in a region of schists; and near Gage, New Mexico, where hübnerite and some scheelite occur with pyrite and lead minerals in a vein cutting limestone.

THE CONCENTRATION OF TUNGSTEN ORES.

The classification and mechanical concentration of tungsten ores are relatively simple because of the high gravity of all tungsten compounds. However, the hydro-mechanical processes are insufficient to ensure complete separation of cassiterite, it being necessary, when this mineral is associated with the ore, to resort to magnetic separators.

There are a number of forms of apparatus used for the concentration of tungsten ores, such, for instance, as the separators of Mechernich, Johnson, Wetherill, Rowand, Knowles, and King. A notable feature in tungsten ore milling is the large table area required per ton of ore treated, which reduces the tonnage capacity, according to experience in Colorado. Screen sizing with a view of eliminating coarse material which might prove worthless, has not been practiced in this country on a large scale; and it has been suggested that this procedure, as well as classification, be more widely considered.

THE CHEMICAL TREATMENT OF THE CONCENTRATES.

The chemical treatment of the mechanical concentrates and the production of tungstic acid are based upon the following general principles:—

(1) The alkaline carbonates with heat attack in the dry way insoluble tungstates to form soluble alkaline tungstates.

(2) Mineral acids precipitate tungstic acid from tungstates in solution in a form insoluble in the liquid present.

(3) Ammonium tungstate is decomposed at redness in an oxidizing atmosphere into tungstic acid.

(4) Tungstic acid and tungstates are attacked by hydrochloric acid gas, forming the oxy-tetrachloride, easily volatile, and decomposed by water into tungstic acid and hydrochloric acid.

(5) Solutions of alkaline tungstates are transformed into

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sulpho-salts by the action of hydrogen sulphide. On decomposing the sulpho-tungstate with a dilute acid, the slightly soluble tungsten trisulphide is formed.

Wolframite may be attacked by *aqua regia,* or by fusion with alkaline carbonates or bisulphates. Decomposition by alkaline carbonates is the method generally used in the tungsten industry. The wolframite is fused, after pulverization, with sodium carbonate with the addition of nitrate. The fusion is done in a reverberatory furnace, usually on a hearth of dolomite agglomerated with tar and burned in place. After the fusion, the mass is broken up, digested with water in filter tanks with methodic washing; nearly boiling water is employed, and the alkaline tungstate dissolves along with silica and phosphoric acid as silico-tungstate and phospho-tungstate of sodium. The metallic oxides remain in the residue. Hydrochloric acid is then added to the solution in a boiling state to acid reaction, when the neutral tungstate passes to the form of para-tungstate, $5Na_2O.12WO_3$, soluble in hot solution, but precipitated in the cold. The silico-tungstate and phospho-tungstate of sodium are more soluble and remain in the mother liquor. The para-tungstate is filtered off, washed, and transformed back again to the normal tungstate by the addition of sodium hydroxide. Tungstic acid is then obtained from this solution by the addition to it, when boiling, of hydrochloric acid. The objections to this process are that large quantities of reagents are necessary and that there are considerable losses on account of the slight solubility of the precipitates. Therefore, Jean suggested heating with calcium carbonate and sodium chloride—a process applicable only to a very pure wolframite, since silica is not eliminated; Gin heats to 1,200-1,300° C. with magnesium chloride or fusion with potassium bisulphate (insoluble potassium acid tungstate is thus formed); while the Kempen Electrochemical Co., heats sodium bisulphate to fusion with mono-hydrated sulphuric acid, then introduces the pulverized mineral. These processes are cited in passing only as examples.

Tungstic acid may be prepared from scheelite by decomposition with concentrated hydrochloric or nitric acid, forming chloride or nitrate of calcium in solution, and an insoluble residue con-

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taining tungstic acid; by fusion with potassium fluoride, producing soluble alkaline tungstate and insoluble calcium fluoride; or by conversion of tungstic acid into oxy-tetrachloride, $WOCl_4$, which boils at 227° C., by means of ferric chloride, and then decomposition of this compound by means of water, to form tungstic acid and hydrochloric acid.

THE PREPARATION OF TUNGSTEN.

Metallic (elementary) tungsten may be prepared by a variety of methods; as for example:—

(1) By reduction of tungsten trioxide (tungstic acid) by means of hydrogen.

(2) By heating the hexachloride in hydrogen.

(3) By heating the trioxide with carbon, in, say, an electric furnace.

(4) By heating the nitride.

(5) By heating to redness a mixture of ammonium tungstate or the trioxide with metallic zinc.

(6) By the passage of an electric current *in vacuo* through filaments of an amalgam of tungsten, cadmium, and mercury; the cadmium and mercury are expelled, while tungsten is left.

Still other processes are the alumino-thermic method, reduction with magnesium, reduction with phosphorus, electrolysis of the double chloride of tungsten and sodium, and by heating tungsten silicide with lime.

Cast tungsten may be prepared in the electric furnace by direct treatment of tungsten trioxide with carbon; reduction with calcium carbide in the presence of silica (not used industrially because the sulphur and phosphorus present are retained by tungsten carbide); or by reduction with ferro-silicon.

Some time ago I made, during the course of an investigation of tungsten filaments for electric incandescent lamps, a study of the reduction of tungsten trioxide by means of carbon. Lack of time will only permit me to present the conclusions, which were as follows:—

(1) When metallic tungsten, obtained by the reduction of tungsten trioxide with carbon, is heated with carbon, the exterior portions of the metal contain carbon.

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(2) When metallic tungsten, obtained by the reduction of tungsten trioxide with carbon, is heated with an excess of carbon, the metal readily forms a definite carbide, W_2C, which possesses many of the properties of the metal, but is more easily attacked by reagents.

(3) When a metallic compound serving as a solvent is present, the chemical action is moderated by dilution, and the combination of carbon and tungsten occurs at lower temperatures, W_2C in all events resulting on heating to a higher temperature.

(4) When pure tungsten trioxide is mixed with carbon and then heated, to effect reduction to the metallic state, a carbide-free tungsten can only be obtained when the quantity of carbon used is insufficient for complete reduction and the temperature employed is below the melting-point of the metal. When tungsten trioxide is heated with an excess of carbon, or in a carbon crucible, the carbide W_2C results; the carbon in excess of that required by the formula is given up as graphite on cooling.

These conclusions, based upon the work of Moissan, Williams, Carnot and Goutal, Lebeau, Greenwood, Borchers, and Defacqz, as well as upon observations of my own, are of considerable. practical importance to illuminating engineers, for they naturally lead to the enquiry, "Do not the commercial preparations, obtained by the reduction of tungsten trioxide with carbon, and especially tungsten filaments for incandenscent electric lamps, formed by heating tungsten with a carbonizable agglutinant, contain tungsten carbide, W_2C?" The physical properties of hard, brittle tungsten—the variety found in commercial lamps before the advent of the new Mazda lamp, and which were brittle and difficult to obtain with a permanent set—and those of pure ductile tungsten remind one of the differences between the tantalum of Berzelius and Moissan and that of von Bolton, since the admixture of carbon with tantalum was ascertained to explain the differences between the observations of the latter and those of his predecessors; and the comparison of non-ductile tungsten with hard and brittle tantalum becomes more relative when it is indicated that their respective atomic weights are 184 and 181.

THE MANUFACTURE OF METALLIC TUNGSTEN AND FERRO-TUNGSTEN.

For the manufacture of tungsten and its alloys on an industrial

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scale, especially for employment in the steel industry, the raw material is usually a concentrate containing from 60 to 70 per cent. of tungsten trioxide. This is mixed with sodium carbonate (soda-ash) and is roasted for about four hours; it is then treated in a dissolver, filtered, concentrated, and allowed to crystallize. Upon filter-pressing, the sodium tungstate remains in the press, and the mother liquor is conducted into a vat for further treatment. The proper amount of hydrochloric acid is added to precipitate the yellow oxide, which, after drying, is reduced to powder metal of 99.25 to 99.50 per cent. purity, with a carbon content of 0.50 to 0.15 per cent. and a density of from 19 to 19.25.

In the production of ferro-tungsten, the concentrates are often mixed with the proper proportion of steel, rod graphite, and a secret compound to assist reduction and fluxing, and the crucibles are placed in a gas-fired crucible furnace and smelted for several hours at a high heat. While, however, an 80 to 85 per cent. tungsten alloy may be made by heating the powdered metal with low-carbon steel scrap in the crucible furnace, yet the higher-grade alloys, such as 85 per cent., are manufactured in the electric furnace directly from the concentrates and steel.

THE PROPERTIES OF TUNGSTEN.

As is well-known, tungsten is usually described, even in treatises issued in 1912, as a very hard powder, ranging in color from gray to brownish black; to quote one author, "resembling sometimes tin, sometimes iron" (Browning). It is true that the metal has ordinarily been obtainable in commerce in the form of a dark gray powder, but in 1910 announcement was made of the production of tungsten in a form in which it is ductile.

Ductile tungsten is prepared by rolling, swagging or hammering a heated body of coherent tungsten until it becomes ductile at ordinary temperatures, and then rolling or drawing to the required size. Ductility and malleability may also be secured by subjecting a coherent body of the metal to a sintering temperature higher than that which would give the maximum mechanical strength to the body if suddenly cooled, continuing this sintering until the metal becomes homogeneous, and then cooling the body

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very slowly, whereby the tensile strength and pliability of the metal is so increased that the body is ductile and malleable (British Patent, 2,759, 1910, of the General Electric Co.)

Ductile tungsten is a bright, tough, steel-colored metal, which may be drawn into the finest wire, much below 1/1000 of an inch. The tensile strength of the wire increases as the drawing proceeds—that is, the more the metal is mechanically worked, the tougher and stronger it gets. Fink has stated that tungsten wire possessing a diameter of 1.2 thousandths of an inch possesses a tensile strength of 580,000 to 610,000 pounds per square inch. The specific gravity values likewise increase with the amount of working. Martin, in 1907, found the density of melted tungsten, 98.96 per cent. pure, to be 16.28, and Weiss reported 18.72 for the brittle metal; Fink, however, found that ductile tungsten, before drawing, had a density of 18.81, and, after drawing to 0.15 inch, a density of 19.30.

Drawn or ductile tungsten retains its luster almost indefinitely, and in this respect resembles the powder metal, which is unchanged in the air at ordinary temperatures. It is readily attacked by fused oxidizing compounds, as sodium nitrate, potassium bisulphate, and sodium peroxide; but hydrochloric, nitric and sulphuric acids attack it very slowly. Tungsten powder is slowly attacked by a mixture of nitric and hydrofluoric acids, and by fusion with alkalies and potassium nitrate. It is also acted upon by chlorine at high temperatures. Tungsten possesses a melting-point of 3,100° C. $\pm$ 60°.

Drawn tungsten has been referred to at some length on account of its interest to the electrical engineer and electrician; reference will be made to its applications under the section *"The Uses of Tungsten."*

THE COMPOUNDS OF TUNGSTEN.

The principal compounds of tungsten are as follows:—

Oxides: Tungsten dioxide, or brown oxide (WO_2);
Tungsten monoxide (WO, or WO_2W_2O);
Tungsten sesquioxide (W_2O_3, or $WO.WO_2$);
Tungsten trioxide (WO_3).
W_4O_3, W_3O_8 ($2WO_3.WO_2$), W_4O_{11}, and W_5O_{14} ($2WO_3.W_3O_8$) have also been reported.

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TABLE II.—HALOGEN COMPOUNDS.

	-Chloride	-Bromide	-Iodide	-Fluoride
Tungsten di-	WCl_2	WBr_2	WI_2	—
Tungsten tetra-	WCl_4	—	WI_4	—
Tungsten penta-	WCl_5	WBr_5	—	—
Tungsten hexa-	WCl_6	WBr_6	—	WF_6
Tungsten oxytetra-	$WOCl_4$	$WOBr_4$	—	—
Tungsten dioxydi-	WO_2Cl_2	WO_2Br_2	—	WO_2F_2 in double salts

Tungsten hexachloride-hexabromide: $WCl_6.3WBr_6$, $WCl_6.WBr_6$

Sulphides: Tungsten disulphide (WS_2); Tungsten trisulphide (WS_3).

Carbides: W_2C and WC.

Silicides: W_2Si_3 and WSi_2.

Nitrides: W_3N_2 and W_2N_3.

Arsenide: WAs_2.

Phosphides: W_4P_2; WP; W_3P_4; and WP_2.

Lnke the compounds of molybdenum, those of tungsten are known in several conditions of oxidation. Of the oxides, the trioxide (WO_3) is the most stable, and it combines with bases to form a large number of salts, the tungstates, of the types R_2WO_4

TABLE III.—TUNGSTEN BRONZES.

Name	Formula	Color	
		Powder	Suspended in water
Purple-red sodium-bronze	$Na_2W_3O_9$	Red	Green
Blue sodium-bronze	$Na_2W_5O_{15}$	Blue	—
Red-yellow sodium-bronze	$Na_4W_5O_{15}$	Brownish yellow	Blue
Golden yellow sodium-bronze	$Na_5W_6O_{18}$	Yellow	—
Potassium-sodium bronze	$5K_2W_4O_{12} + 2Na_2W_5O_{15}$	Red	—
	$3K_2W_4O_{12} + Na_2W_5O_{15}$	—	—
Potassium-bronze	$K_2W_4O_{12}$	Blue	Greenish
Lithium-bronze	$Li_2W_5O_{15}$	Dark blue	—
Potassium-lithium-bronze	$3K_2W_4O_{12} + Li_2W_5O_{15}$	Blue	Green

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(*normal*), $R_2W_4O_{13}$ (*meta-*), and $R_6W_7O_{24}$ (*para-*). The alkali tungstates are the most important soluble salts, and of these the chief are the sodium tungstates, especially normal sodium tungstate, $Na_2WO_4,2H_2O$.

Tungsten trioxide forms a number of complex acids with the acid oxides of boron, silicon, phosphorus, arsenic, antimony and iron; and in this manner a very large number of complex salts, of no technical importance as yet, have been prepared.

The so-called "tungsten-bronzes" are an interesting series of tungstates, the technical application of which I shall refer to later. The most important of these are given in Table III.

THE USES OF TUNGSTEN.

(1) *In the Production of Special Steels.*—The most important use of tungsten is in the steel industry.* The introduction of tungsten into tool steel imparts to it the property of holding its temper at a much higher temperature than high-carbon steels; thus, when lathe tools are made from tungsten-steel, the lathes may be speeded up until the chips leaving the tool are so hot that they turn blue. It is said that about five times as much work can be done by a lathe built for such speeds and work, and fitted with tungsten-steel tools, as can be done by the same lathe with carbon-steel tools. Sixteen to 20 per cent. of tungsten is ordinarily used in lathe tools; 1.5 to 3.5 per cent. in some saws; while in hacksaws larger percentages are used. Tungsten is now used in making steels for permanent magnets, for employment in magnetos, indicators, etc.; it is said to be very useful for the production of rails for use on curves and of cast steel car-wheels; and it is being specified by some governments for toughening armor plate and for projectiles. One of the hardest steels ever reported contained 0.68 per cent. carbon, 3.01 per cent. chromium, 19.37 per cent. tungsten, and 0.04 per cent. silicon; the Brinnel

* The class of tungsten steels made to-day is very extensive, ranging from the ordinary bar steels containing 0.5 per cent. or more tungsten to the highest grade tool steels, which may carry up to 25 per cent. tungsten. Finishing and intermediate steels contain from 2 to 5 per cent.; self- or air-hardening steels, from 4.5 to 12 per cent.; and high-speed steels, from 14 to 26 per cent. One satisfactory magnet steel analyzes: tungsten, 5.47 per cent.; carbon, 0.57; silicon, 0.18; and manganese, 0.26 per cent. Tungsten-vanadium magnet steel analyzes about as follows: tungsten, 7.00 per cent.: vanadium, 0.30; and carbon, 0.60 per cent.

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ball test gave it a figure of 866. A new steel, extremely hard, which withstands the oxy-acetylene blowpipe was exhibited by Dr. Carl Duisberg at the Eighth International Congress of Applied Chemistry, but its composition was kept secret. Tungsten also increases the vibratory response in sounding plates and wires for musical instruments.

Tungsten is reported to work satisfactorily with all other alloy-metals, and is used in combination with nickel, vanadium, chromium, and molybdenum. It improves chrome-nickel-vanadium steel; vanadium spring steels are said to be improved by the addition of some tungsten; and for steel castings, 0.25 to 1.00 per cent. tungsten is used, sometimes along with up to 1 per cent. chromium.

Ferro-tungsten, an alloy containing from 40 to 82 per cent. tungsten, is usually used in the steel industry in the production of special alloys, since, it is claimed, that much metallic tungsten is lost, owing to its finely divided condition, both through oxidation and in the slag. However, tungsten metal (97 to 99 per cent. pure) is used in the manufacture of the highest class steels, since its high percentage of tungsten and small bulk make it especially desirable for crucible work. When it is used for open-hearth steels, it is usually placed in small metal containers which are melted with the charge.

In the normal 3 per cent. tungsten steels, the tungsten is probably present as an iron tungstide, perhaps, according to Swinden, as Fe_3W.

(2) *Tungsten Alloys.*—In addition to alloying with iron, tungsten forms alloys with nickel, copper, tin, aluminum, lead, and a number of other metals. *Sideraphit* is a combination of iron, nickel, and aluminum-copper, containing 4 per cent. tungsten; *Minargent* contains copper, nickel, and tungsten; and *Pladinoid* is composed of 60 per cent. copper, 25 per cent. zinc, 14 per cent. nickel, and 1 to 2 per cent. tungsten. *Partinium* is composed of aluminium and tungsten, and is used in automobile construction. The alloy with aluminum and copper has been used in propeller blades. These are but a few of the many alloys containing tungsten, and are cited only as illustrations.

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(3) *In the Manufacture of Filaments for Electric Incandescent Lamps.*—While from 97 to 99 per cent. of the tungsten produced is said to be used in the steel industry, one of the most interesting applications of the metal is in the manufacture of filaments for electric incandescent lamps.

The history of the tungsten filament, which has had so great an effect on the lighting industry, has been frequently discussed in the extensive literature of tungsten, and the Austrians have almost unanimously received the credit of its invention. This is, however, incorrect, although they deserve much of the credit for its development.

In the early part of 1887, an American, Turner D. Bottome, conceived the idea that the metal tungsten possessed properties which rendered it especially suitable for an incandescent lamp filament, being of fairly high resistance and of high melting-point. During the development of Bottome's invention, some parties made strong efforts to get possession; but, through the assistance of J. B. Tibbits, of Hoosick, N. Y., the patents were secured. Bottome's application was filed on September 29, 1887, and was allowed on April 9, 1889, the number being 401,120. Bottome also took out a patent for treating the filament, dated August 6, 1889, and numbered 408,286. Tibbits assigned the English rights of the invention to H. H. Lake, of London, and English Patent 6,104, April 9, 1889, relates to a method in which a carbon filament is prepared in the ordinary manner and then soaked in a saturated solution of tungsten trioxide dissolved in any of the fixed alkalies, after which it is rendered incandescent by a current of electricity in an atmosphere of pure dry hydrogen, the result being that metallic tungsten is deposited upon it, "which makes it much tougher and more durable." It is apparent, therefore, that Bottome devised a process of utilizing refractory tungsten for coating carbon filaments, thus being the first, to my knowledge, to make use of tungsten in the production of filaments for incandescent electric lamps.

For the production of tungsten filaments various methods have been worked out since 1903, from which date the development of the tungsten lamp begins. A number of advantages were recognized which made tungsten available for use as a filament:—

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(1) The high temperature at which it fuses;
(2) The whiteness of the light;
(3) The high efficiency and long life; and
(4) The fact that thousands of filaments may be made from a pound of tungsten.

The great drawback to the use of tungsten lamps was early shown to be that the filaments were usually very brittle and that the loss from shock was large. Consequently, many investigations were conducted with the view of remedying these defects, and the patent literature is, as a result, quite extensive, 50 patents having been granted in Germany alone from 1903 to 1908. On account of the importance of the subject to the electrical engineer, I shall now outline some of the more important processes.

Just and Hanaman (German Patent, 154,262, September 8, 1904) started from the idea of producing a coating or deposit of tungsten on a core of carbon. As is well-known, the oxychlorides of tungsten and molybdenum, when heated to a red heat, are reduced by hydrogen, forming metal, hydrochloric acid and water. If, therefore, a carbon or metallic filament is heated to incandescence in an atmosphere of tungsten oxychloride vapor with an excess of hydrogen, the reduced tungsten is deposited on the filament, which then consists of a core of carbon or metal with a sheath or covering of tungsten. Having ascertained these facts, Just and Hanaman devised the following process (French Patent 347,661, November 4, 1904): Tungsten or molybdenum, or an alloy of these, is mixed with an organic agglutinant, and the carbon is eliminated by placing the filaments in an atmosphere of, say, oxychlorides of these metals in the presence of a feeble current of hydrogen, and then heating the filaments to redness, to effect a substitution of tungsten or molybdenum for carbon. It was learned that the conditions under which the reaction occurred with the oxidation of carbon were an excess of oxychloride, the presence of very little hydrogen, and a high temperature in the filament. This method, I may note, is entirely analogous to a method patented by Blau in 1901 for transforming a carbon filament into osmium in an atmosphere of osmium tetroxide.

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The method of Just and Hanaman discussed above is known as the "substitution method," of which some modifications are mentioned in English Patent 11,949, of 1905; German Patent 184,379, of 1905; and United States Patent 878,463, of 1908.

In the "paste method" of Just, which is analogous to Auer von Welsbach's method of making osmium filaments, tungsten compounds reducible by hydrogen are pulverized and mixed with a binding material free from carbon, formed into a paste, pressed into filament form, and reduced in an atmosphere of hydrogen. This process was devised with the view of avoiding the use of carbon, the thorough removal of which was found to be the chief difficulty in the substitution processes.

According to French Patent 358,272, October 4, 1905, Just and Hanaman specify that if the fused metal, which always contains some carbide, be used as the starting material, it is first *drawn* into wires, and these are then heated *in vacuo* by means of a progressively increasing current, so as to distil off the carbon. In the Third Addition to French Patent 347,661 of 1904, dated February 14, 1906; and in German Patent 200,300 of 1905, it is stated that tungsten filaments obtained as in the original patent are amorphous and break easily. By incorporating with the tungsten a small amount of certain more readily fusible metals, as chromium, vanadium, tantalum, etc., it was claimed that the filament during the final heating fused so far as to assume a crystalline character, whereby its fragility was overcome. In the Fourth Addition, dated February 19, 1906, it is specified that a filament of carbon or metal, or a mixture thereof, is coated with tungsten by heating it electrically in a low-pressure atmosphere of hydrogen containing a gaseous compound of the metal.

The development of the tungsten lamp by the processes of Just and Hanaman took place in the lamp works of the Vereinigten Elektrizitäts A.-G., in Ujpest, which owns the licenses for Austria and Hungary, Russia, Belgium, Italy, Spain, and Portugal. The German rights are controlled by the Wolfram-lampen A. G. in Augsburg, which concern has transferred the monopoly of manufacture to George Lüdecke & Co., in Lechhausen. The Wolfram-lampen A. G. took out a number of patents in addition to those already mentioned.

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In a 110-volt, 32 candle-power tungsten lamp of Just and Hanaman in use in 1906, there were three exceedingly thin filaments of tungsten, held in place by stays of aluminum oxide. The average life of a 110-volt, 40 candle-power lamp, when consuming one watt per hefner candle, was stated to be 1,500 hours, it being also claimed that the illuminating power of the lamp remained almost unaltered during its entire life and that it was not at all sensitive to fluctuations in the supply pressure.

One of the most interesting of the patented methods of producing tungsten filaments was the process of Hans Kŭzel, in which the difficulty of having to remove carbon was overcome. The invention of Kuzel was based upon two essential features: One point was the establishment of the fact that metals in the colloidal condition formed plastic masses without the addition of a binding material and could then be formed into wires readily. The second point was that wires formed in this manner and dried underwent a physical change when subjected to a strong heat: without breaking or disintegrating into a pulverulent form, it was claimed that they passed over into the crystalline state from a colloid condition, and that the filament was thereby finished.

In English Patent 28,154, December 22, 1904, Kŭzel details his process. A plastic mass in a colloidal state, without the addition of any binding material, is brought into the desired shape, dried slowly, and finally raised to a white heat in a neutral atmosphere. To obtain the plastic masses, the metals are obtained as colloidal suspensions, for example, by Bredig's method, which consists in setting up a voltaic arc between two electrodes made of the metal, having a rough surface and immersed in water. The colloidal suspension is then dried by slow evaporation, to reduce it to a pasty condition. Kŭzel obtained a number of other patents for improvements on and modifications in his process. The German patents of Kŭzel (5 in number) were assigned to Pintsch Brothers in Berlin, while the firm of Kremenecky, in Vienna, commenced the manufacture of Kŭzel lamps.

The Kŭzel lamp of 1906 showed a power consumption of about 1 watt per hefner candle, but the hope was expressed by the manufacturer that it might be reduced to one-half watt per hefner candle, with a useful life of from 1,000 to 1,500 hours.

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A lamp of this type examined in 1909 contained a filament which consisted of four loops, each of which was mounted in a peculiar spiral shape and hung loosely enough to permit of contraction. The joints between the filaments and base spires were fused as in an American lamp manufactured by the Auer process. The filament had a total length of 19.87 inches, a diameter of 0.00138 inch, and a total surface area of 0.0859 square inch. It possessed a smooth shiny surface, broken only by what appeared to resemble fine cracks, similar to the fine check cracks sometimes seen in the glazes of porcelains. Such a smooth polished surface would naturally have a high emissivity. The lamp possessed a mean horizontal candle-power of 21.1 and a mean spherical candle-power of 17.7. When tried out under two conditions—(*a*) 25 were burned upon a well-regulated voltage, supplied by a storage battery floating across constant voltage mains; the racks being supported, moreover, by three coil springs to protect from vibration. (*b*) 25 were operated upon 60-cycle alternating current mains having a badly fluctuating voltage; the rack, in this case, being supported by rigidly fastening to the floor—the following results were obtained by Amrine and Guell:—

	A.	B.
Cost	$1.08	
Mean horiz. C. P.—		
(a) New	19.9	20.6
(b) 1,000 hours	18.2	—
(c) 2,000 hours	15.0	—
Average watts	27.5	27.4
Life in hours	762.0	434.0
C. P. through life	18.2	20.2
Cost for 1,000 hours		$ 2.64
Cost for 2,000 hours	$70.28	—
C. P. hours a lamp	36,400	20,200
Total C. P. hours	910,000	505,000
Kilowatt hours	1,375	685

Carl Auer von Welsbach, whose remarkable work has been of such immense inmportance in creating the modern methods of illumination, both in gas and electric lighting, devised a process for the production of tungsten filaments which was a development of the process for making osmium filaments, tungsten being used instead of osmium as the basis of the filament.

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According to the Welsbach patents (French Patent 357,842, September 18, 1905; German Patent 182,683, January 18, 1905), filaments for electric incandescent lamps are made from tungsten, etc., by adding to the finely-pulverized metal, combustible organic agglutinants, such as sugar, gum or a suitable viscous liquid, together with some lamp-black, and forming the resulting paste into threads. The threads are dried and heated at a moderate temperature without access of air. Finally, the filament is ignited with the aid of the electric current in an atmosphere of reducing gases, principally hydrogen, containing small amounts of oxidizing agents, especially water vapor. In French Patent 357,868, September 19, 1905, and in English Patent, 18,814, September 18, 1905, provision was made for the reduction of tungstic acid. French Patent, 379,379, June 28, 1907, provided for the elimination of the carbon from the filament of crude tungsten by the action of hydrogen, or hydrogen diluted with nitrogen, which contained not more than 1 per cent. (of the hydrogen) of water-vapor; and further improvements were claimed in English Patent 28,775, December 17, 1906; German Patent, 184,705, March 28, 1906; and French Patent 372,537, December 13, 1906. According to French Patent 392,455, July 18, 1908, the removal of carbon from metallic filaments is effected by treating them with sulphur at a high temperature in the presence of hydrogen.

The Austrian Welsbach Company were among the first to place tungsten lamps on the market for voltages of 100 to 120, and consuming one watt per hefner candle. Their lamps were tested in the laboratories of the Municipal Electricity Works of Vienna, and the above figure for power consumption was confirmed; the results obtained up to 1,000 hours of burning were said to be favorable. In 1906, the Welsbach Company announced that during the next season they would place on the market modifications of their osmium lamp, for which they would use the trade-names "osmim" and "osram" lamp. The chief constituent of these lamps was tungsten.

From tests made by the German Reichsanstalt it seemed that the "osram" lamp consumed about 1 watt per hefner candle, the average life being 1,000 hours. The best lamp consumed

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1.10 watts per candle-power after 1,000 hours and gave 27.3 candle-power; the worst gave 25.7 candle-power and consumed 1.22 watt per candle-power. This was probably the first official test of any tungsten lamp made public, and it is important to mention that the above tests were made with alternating current.

The lamps made in the United States in 1909 in which the filaments were manufactured by the paste or Auer process, contained a mounted filament consisting of four hairpin loops connected in series and mounted on supporting spires. Connections between the loops were made at the base end of the stem by fusing together the filaments and the spires. The filaments were hung loosely on the spires so as to permit the contraction which occurred after they had been burned for a while. The filament possessed a length of 19.27 inches, a diameter of 0.00163 inch, and a total surface area of 0.0987 square inch. The filament was covered with small depressions and wrinkles which rendered its emissivity somewhat less than that of the Kŭzel filament; but the surface of the filament was found to be superior to that of a filament manufactured by the deposition process. The Auer filament was said to have better lasting qualities than those manufactured by the Kŭzel and the Just and Hanaman processes, and the mounting was found to be very good.

The Siemens und Halske A.-G., of Berlin, Germany, has taken out a number of patents on the manufacture of electrical glow-lamps with incandescent bodies of tungsten or similar metals. According to German Patent 181,050, of 1904; English Patent 23,097, of 1905; and French Patent 359,339, of 1905, tantalum is used as a core upon which another difficultly fusible metal, as tungsten, is deposited. An alloy is then formed by heating to a very high temperature. Later patents of this company pertained to the production of filaments by stamping tungsten powder into a pipe composed of ductile metal, as tantalum or iron, then drawing or rolling into filaments, and removing the skin of metal chemically (German Patent 197,382, of 1906; English Patent 4,814, of 1907; and U. S. Patent 936,403, of 1909). According to English Patent 3,174, of 1907, the bodies obtained in this manner are very ductile. Patents were also obtained by this

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company for the production of filaments by reduction of nickel tungstate, and volatilization of the nickel; by coating tungsten powder galvanically or chemically with a ductile metal, working up into a filament, and then eliminating the encasing metal; and by a number of other processes developed along definitely scientific lines, due, no doubt, to the ingenuity of Werner von Bolton, so well-known for his researches on tantalum, niobium, and vanadium.

In the process used by the Westinghouse Metal Filament Lamp Co., a mixture of 400 grams of tungsten trioxide and 800 grams of powdered zinc were heated to 800° C. for an hour; the powder was pulverized after cooling, and then treated with ½ liter of hydrochloric acid (1.12) and a small amount of nitric acid. After repeating this, to remove all the zinc and zinc oxide, the acid was expelled and the mass washed. It was then evaporated to the consistency required for squirting into filaments, which were heated in a furnace to 800° C. for 30 minutes. After cooling, they were treated with an electric current to a white heat in an atmosphere of nitrogen or hydrogen.

The development of the processes of the General Electric Co., has been of the greatest interest. In 1906, this company claimed a process wherein "nitridamide" of tungsten was mixed with a carbonaceous binder, the carbon being removed by oxidation; in the same year the use of a cadmium amalgam along with tungsten was introduced by Coolidge, the volatilizable metals being expelled by heat after squirting into filaments; and then an alloy of bismuth and cadmium was proposed in the place of the amalgam, and later an alloy of cadmium and lead was used as the binding material.

Whitney hit upon the idea of compressing tungsten powder, which had been prepared by reducing tungsten trioxide in hydrogen. On subjecting tungsten powder, placed in a mould, to a pressure of about 3,000 pounds to the square inch, it was found that the particles adhered sufficiently to admit of handling as one piece. The pencil or rod thus produced is inserted in a powerful electric circuit and heated by the passage of the current until the particles sinter together (about + 2,650° C.). The device is most ingenious. One end of the rod is attached to a copper disc

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which floats upon a cup of mercury, acting as one terminal. The other end is attached to a heavy leading-in copper wire which, duly insulated, passes through a water-jacketed copper bell-jar, which rests in a tank of mercury. Hydrogen is driven into the apparatus under sufficient pressure to cause it to bubble through the mercury at the bottom. One may imagine, if not perceive, the brilliancy of a rod one centimeter in diameter and twenty centimeters in length as it approaches the melting-point of tungsten with the increase of the current. The rod becomes solid metal, and is subsequently heated and swagged in an atmosphere of hydrogen. When of a sufficiently small diameter, the wire is drawn through diamond and, more recently, alundum dies.

ANALYSES OF SOME TUNGSTEN FILAMENTS.

You may be interested in hearing of some work I carried out not so long ago in an interference suit, that once looked as if it might be one of the most sensational character. Five lamps were placed in my hands, with dated slips of paper sealed within the throats of the lamps. My instructions were to learn the composition of the filaments and, of course, save enough to serve as *corpora delicti*. The total weight of one of the filaments was a little over two milligrams. They ranged in weight up to fifty milligrams. We were able to determine the ratio of W to WO_3 by oxidizing portions of the precious filaments with nitric and hydrofluoric acids. The reagents were applied in droplets from a platinum rod and kept under constant observation by means of a magnifying glass. Precautions such as are required in making atomic weight determinations were taken. An atomic weight balance, sensitive to 1/100 milligram, was used for filaments where as much as 20 milligrams were available. When we were reduced to 3 milligrams or less, we had recourse to a Nernst quartz-fiber torsion-balance, sensitive to 1/1,000 milligram. The balances were set upon stone piers built through the floor upon a solid rock foundation. To avoid disturbance due to some blasting in the neighborhood, the final weighings were accomplished by nearly continuous labor from noon on Saturday to 6 A. M. the following Monday morning. Most valuable service was rendered by my colleague, Dr. Stevenson, who made the actual weighings. We found it necessary to construct special

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basket platinum crucibles with a total weight of about 2 milligrams for the determinations with the smallest filaments. To prove out our method, preliminary determinations were made with Mazda, Westinghouse, and Just filaments. The values obtained are given herewith.

A. Using Atomic Weight Balance sensitive to 1/100 mgm.

	Amount of filament used	Percentage of tungsten
Mazda	0.04166	100.33
Westinghouse	0.01959	100.18
Just	0.01538	99.56
No. 5	0.02956	100.48
No. 4	0.01922	99.93
No. 3	0.02537	93.57*

B. Using Nernst Micro-balance sensitive to 1/1,000 mgm.

	Amount of filament used	Percentage of tungsten
Mazda	0.003260	99.47
Westinghouse	0.004306	99.55
Just	0.003075	99.39
No. 2	0.003156	99.87
No. 1	0.000830	98.00

The ratio of W to WO_3 is 1.26; the ratio of W_2C to $2WO_3$ is 1.22. The factor, if the filament were tungsten containing ten per cent. tungsten carbide, is 1.256, so it is apparent that it was quite impossible, on account of experimental error, to tell whether the filaments contained any carbides.

The material obtained in these determinations was then used for spectroscopic observations. A Steinheil Grating (14,000 lines to the inch) spectrograph was used, whereby the arc spectra were photographed side by side on one plate. Spectrographs of thorium, zirconium, tantalum, titanium, columbium, vanadium, molybdenum, tin, and various mixtures of these with tungsten were also made for comparison. The filaments proved to be tungsten. Whether they contained carbon—very likely they did—I was unable to prove. However, for reasons I need not give, the case never came to trial. Although there was no contention as to the real composition of the filaments beyond the matter of tungsten itself, it would have been interesting to learn whether any carbides were there, as it was claimed that the filaments were

* Perhaps an alloy.

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made prior to the real advent of tungsten filaments, the early production of which, as already noted, was dependent upon carbon or carbonaceous material as a reducing agent.

(4) *Other Uses of Metallic Tungsten.*—Metallic tungsten is used in the manufacture of small crucibles for use in the electric furnace. These may be made by mixing tungsten powder with a small amount of an agglutinant and then pressing the mixture into the desired shape, after which it is sintered in an electric furnace. The crucibles, when used, are lined with an inert, infusible substance, such as thoria, for, when heated, tungsten combines with many substances.

It is only to be expected that a metal having such properties as ductile tungsten should find applications other than that for incandescent electric lamps. Wrought tungsten has been substituted successfully for platinum and platinum-iridium as contact points in spark coils, voltage regulators, telegraph relays, etc. Coolidge and Fink are authorities for the statement that the service far exceeds that for platinum and platinum-iridium contacts, owing to the greater hardness, higher heat conductivity, and lower vapor pressure of tungsten as compared with platinum.

Tungsten is also used in furnaces of two types: the type described by Winne and Dantsizen consists of an alundum tube wound with tungsten wire; and the second type is constructed on lines similar to the Arsem vacuum furnace, excepting that a tungsten metal tube replaces the helical carbon resister.

Tungsten gauze has been used successfully for separating solids from acid liquors, and this gauze may find commercial applications, as in the removal of sludge from copper refining baths.

Wrought tungsten is well-suited for targets or anti-cathodes for Röntgen tubes; in fact, it has been shown that the high density, high melting-point, high heat conductivity, and low vapor pressure render tungsten a far more efficient target than any other metal.

The General Electric Company is at present investigating the thermo-electric properties of the couple, tungsten-molybdenum; it is reported that this couple is very convenient for high temperature measurements in the tungsten-hydrogen furnace. This Company has also taken up the study of the electrochemical be-

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havior of tungsten and has made up a series of cells and combinations.

Among other applications of ductile tungsten are the following: A material for standard weights; owing to its chemical stability, the finest sizes of wire are well adapted for galvanometer suspensions, for cross-hairs in telescopes, and in surgical operations in place of gold and silver; the wire may be used in musical instruments; the metal could be used in climates where steel is readily corroded; it can be used in making acid-proof dishes and tubes; the wire recommends itself as a unit resistance, owing to its purity, ease in duplication, and non-corrodibility; since it is non-magnetic and elastic, it is being tried out in electrical meters, replacing the phosphor-bronze springs, and similarly watch springs could be made which would not become corroded or magnetized. Other mentions are: tungsten pen points, drawing ties, knife blades, meter-bearings, reinforced asbestos curtains, fire-proof coverings, etc.

Colloidal tungsten has been employed as a substitute for bismuth in Röntgen sketches of the gastro-intestinal canal.

THE USES OF SOME TUNGSTEN COMPOUNDS.

In conclusion, I shall refer briefly to the use of some of the more important compounds of tungsten.

Tungstic oxide has been used as an oil and water color. Large quantities of sodium tungstate are manufactured, much of which is used in fire-proofing cloth for curtains and draperies, and as a mordant in dyeing. Other tungsten salts are used in weighting silks. When silks are dyed, tungsten salts, owing to their high specific gravity, are introduced to give more apparent weight to the fabric. Sodium tungstate has almost exactly the same rate of expansion for moderate temperatures as platinum, so that it is used for sealing platinum apparatus in making water determinations in chemical analyses of rocks. Calcium tungstate, on account of its fluorescence, is used as a screen to make X-rays visible. Tungsten compounds have also been used in glass and porcelain coloring, and in making certain bronze powders. Tungsten bronze is made by dissolving tungsten trioxide in melted sodium tungstate; the gold-like leaflets are used as a pigment.

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There is also a violet tungsten bronze: $K_2W_3O_9$ mixed with W_2O_5. Sodium phosphotungstate is used as a reagent for alkaloids. Cadmium borotungstate (sp. gr. 3.28) is used for the mechanical separation of minerals. Lead tungstate has been substituted for white lead in paints.

I can not close without expressing my great thanks to Doctors Whitney and Coolidge of the General Electric Co.,; Mr. Lay, of the New York Edison Co., for some of the splendid exhibits you have been privileged to see; and to my assistants, Messrs. Stokes and Joralemon, who patiently and efficiently assembled the experiments.

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RADIO ENGINEERING AT THE COLLEGE OF THE CITY OF NEW YORK.*

By Alfred N. Goldsmith, Ph. D., Director of Laboratory for Research in Radio-Communication and Photo-Physics, College of City of New York.

Progress in the art of "wireless" telegraphy, since its feeble beginnings about fifteen years ago, has been extremely rapid. Nearly all the pioneer workers in the field of radio-communication are still not only living but active in their researches. Within half a generation a new branch of engineering has arisen, and radio engineering promises to be an important and highly interesting branch of electrical engineering.

The civilizing and socializing influence of an efficient means of communication can hardly be overestimated. In mediaeval times, when messages and men travelled but slowly, *stranger* and *enemy* were synonomous terms. But modern and efficient means of communication and transportation have largely contributed to the ever-increasing solidarity of mankind. For this reason alone, the utmost encouragement of radio engineering is justified.

But there are other equally potent reasons for the development of this art. The isolation of ships at sea in times of storms or of fair weather has been broken by our winged electrical messenger and the listening ears of all radio stations are attuned to the faint and distant call for help.

With these strong incentives toward its study, radio engineering has unaccountably lagged in America. There have been but few properly equipped laboratories in which the highly complex phenomena of transmission and reception could be profitably studied. Empirical methods were unfortunately customary, and no university or college until recently offered to train its students in the engineering and quantitative side of radio transmission.

It was long felt by the writer that there was a pressing need for such a course, particularly in New York, the center of the industry in America. But financial considerations were in the

* Outline of a lecture delivered at the 313th Meeting of the New York Electrical Society, October 29, 1912, in the Laboratory for Research in Radio-Communication and Photo-Physics, College of City of New York.

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way. The old ideal of the university—an instructor at one end of a log, the student at the other—cannot be applied satisfactorily to scientific subjects. Expensive and delicate equipment in large quantities is urgently needed.

The generosity of one of our most worthy and faithful alumni, Mr. Gano Dunn, past-president of this society and of the American Institute of Electrical Engineers, has enabled the establishment of a thorough course in radio engineering having for its aim the exact and detailed study of that subject. That is, the theory, design, construction and maintenance of radio apparatus is the ground covered.

In the theoretical portion of the course, radio frequency alternating current phenomena are studied with particular reference to the cases arising in "wireless" work. The typical circuit containing resistance, inductance and capacity is carefully considered, and then the phenomena in such circuits connected through various types of couplings. Electric waves in wires and in space, the mechanism of radiation and reception, and the current theories concerning long distance transmission are then considered. Special portions of electrical engineering, not ordinarily covered in sufficient detail for the purposes of the radio engineer, as for example the design of high-tension transformers, are also treated. The basis of this mathematical work is found in the articles of Bjerknes, Drude, Wien, Zenneck, Fleming, Sommerfeld, and other well known workers in this field.

In the engineering construction portion of the work, every type of apparatus used in radio transmission is studied in detail. Relative advantages and disadvantages, such as the possession or lack of portability, precision, ease of manipulation, constancy of calibration and simplicity in manufacture are considered. By many references to the extensive literature of this subject the student gains a reasonably full knowledge of the latest types of apparatus manufactured by each of the leading companies in this field, and is thereby given a correct perspective enabling him to justly appraise the advantages and defects of the various systems. A number of large and small stations and factories are visited by the class and the technical problems of construction and installa-

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tion work and modern methods of maintenance are observed first hand.

The laboratory portion of the course has been carefully developed in such directions that the experiments find daily application in the work of the radio engineer. Purely arbitrary technical and intellectual difficulties have been introduced in some of them, however, to train the men to meet unexpected emergencies and defects in apparatus. The precise and approximate measurement of inductance, capacity, radio frequency resistance, wave lengths, decrements, coupling coefficients, high-tension and radio frequency current measurements, the sensitiveness of detectors, the efficiency of stations or parts thereof, and various allied topics, are treated in this portion of the course.

The present equipment of the laboratory consists in part of the following. In the center of the accompanying illustration are seen the three arcs (and auxiliary equipment) of the Poulsen undamped wave sets, which were the gift of Mr. Dunn. There are included in this auxiliary equipment high and low-tension switchboards and measuring instruments, a motor-generator, automatic and manually operated antenna switches, regulating rheostats, choke coils, transmitting and receiving inductances, couplers and capacities, as well as many special pieces of smaller and supplementary apparatus. In addition, the equipment of the laboratory comprises quenched-spark apparatus, ordinary spark sets, motor-generators of various frequencies (situated in the Electrical Laboratory) and a considerable amount of precision measuring and standardizing apparatus. Among the latter may be mentioned standard electrostatic voltmeters and hot-wire ammeters, wave meters, hot-wire and d'Arsonval galvanometers, standard inductances, standard condensers, and inductance and capacity bridges. A sufficient supply of small parts, such as detectors, switches, and exciting buzzers insure freedom from delay in setting up experiments.

The course lasts two terms, with six prescribed hours of attendance per week. Elementary and advanced physics, including advanced electricity, are prerequisities. Direct and alternating-current engineering work is always required in part as pre-

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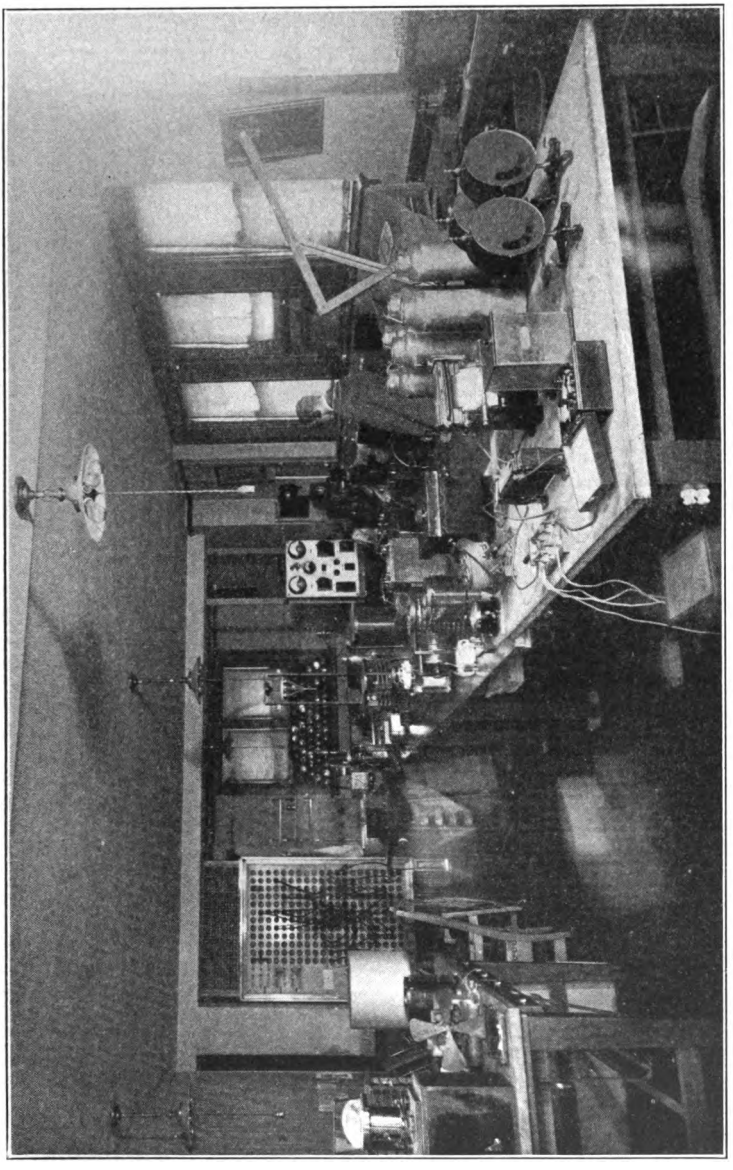

Laboratory for Research in Radio-Communication and Photo-Physics, College of City of New York.

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requisite and in part as corequisite. This insures that the student shall be properly prepared for the course.

Specially qualified students are also granted the privilege of carrying on special researches in this field. At present two such researches are in progress, and the results thereof will be duly published. In addition, special facilities are provided to enable the instructor to carry on research work and special tests.

An extremely practical feature of the course is the form of the final examination. Instead of questioning the student on a few arbitrarily chosen topics, and thus revealing only partly his mental acquisitions, the examination consists in the complete design of a station to meet practical conditions. The student is given approximately eighty days in which to meet the requirements of the examination. The location, range, and general purpose of the desired station is given him (each student having assigned to him a different type of station), and he is required to furnish full electrical and mechanical data on all parts of the station and apparatus, accompanied by sketches of the apparatus, close cost sheets, and estimates of the time required for manufacture and installation. Considerable care has been taken to make the requirements of the specification correspond with great exactitude to actual and practical cases, and it is felt that the student who satisfactorily meets the conditions set is a fairly competent radio engineer. The watchword of the course is—scientifically correct (and financially profitable) design, and precision measurement, both based on comprehensive and exact theory.

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New York Electrical Society

THE purpose of the New York Electrical Society, founded in 1881, is to present in popular but none the less authoritative form, the latest advances in the electrical and allied sciences and arts, and to encourage professional and social relations among its members. All persons in good repute and interested in electricity and its applications, are eligible to membership.

Upon request, an application blank and list of members will be forwarded by the Secretary. When returned filled in with the name, address and occupation of the applicant, and with endorsement by two members of the Society, the application, upon approval by the Examining Committee, will be presented for action at one of the regular meetings of the Society.

The entrance fee is $1.00, and the annual dues, $3.00.

GEORGE H. GUY, Secretary, Engineering Societies Building,
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NEW SERIES 1912 NO. 2

Transactions

of the

New York Electrical Society

Organized 1881

Biographical Sketch of Horatio A. Foster

BY

W. D. Weaver

Reminiscences of an Electrical Engineer

BY

Horatio A. Foster

The New York Central Terminal

BY

Carl Schwartz

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An Organization for the Dissemination of the Knowledge of Electricity and its Applied and Allied Arts, and for the Promotion of Social Relations among its Members.

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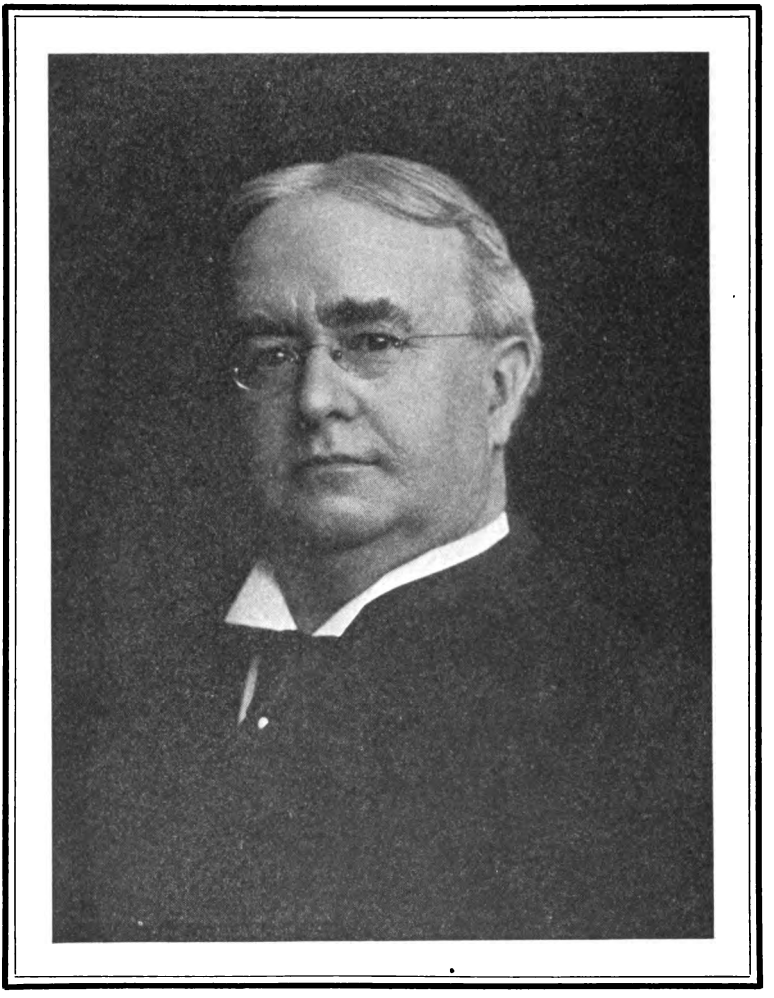

HORATIO A. FOSTER.

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TRANSACTIONS

OF THE

New York Electrical Society

NEW SERIES 1912 NO. 2

HORATIO A. FOSTER.

While the paper by Mr. Horatio A. Foster, contained in this issue of the *Transactions,* was under preparation for publication, its author died suddenly on April 27, 1913, from heart disease, in the Grand Central Subway Station, New York. At the time of his death he was in his fifty-fifth year. He is survived by a widow and a son.

The details of Mr. Foster's professional career are so fully given in the paper which follows that few particulars remain for notice. His first literary venture was a book published in 1895 and now long out of print, entitled "Central Station Book-keeping." This represents perhaps the first attempt at the formulation of a systematic method of central station accounting, the great need of which was impressed upon the author during his service as electrical expert agent for the Federal Census of 1891-2. His paper on the "Cost of Steam Power," presented in 1897 before the American Institute of Electrical Engineers, to which reference is made on page 50 following, retains much of its original value owing to the full and carefully derived cost data included of steam plants ranging in size from almost the smallest to the largest of the day. The data tabulated and discussed were obtained both from tests and the examination of accounting books of manufacturing establishments operating steam plants, this search frequently revealing unsuspected items chargeable to operating cost.

For a time about 1895, Mr. Foster was editor of *Electric Power,* a monthly magazine published from 1889 to 1897, which did excellent pioneer service in advocating the use of electric power in a period when the electric motor had little industrial

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status. The "Electrical Engineers' Pocket-Book," first published in 1901, was an immediate success and in its many editions has continued to be an indispensable data book for the engineer and the student. Mr. Foster's last contribution to professional literature, entitled "Engineering Valuations for Public Utilities and Factories," was issued in 1912 and has an exceptional value through representing the observation and experience of the author in a line of work he had in recent years made a specialty.

Possessed of a charming personality, Mr. Foster made hosts of warm friends wherever he dwelt, and it has been said of him that he never made an enemy. But the great lesson that his successful career teaches is the professional value of high character. Though an engineer of ability and endowed with an analytic faculty that gave to his reports an unusual value, it was this moral qualification possessed to an eminent degree that frequently brought clients who otherwise might have felt inclined to make their selection from among men of greater technical education. With a native shrewdness of which he was apparently unconscious—a qualification that gave a wide range to his activity and assured successful accomplishment of any task undertaken—were united scrupulous recognition of obligations assumed, and an intellectual as well as personal honesty that made him an honor to the engineering profession and, in all circles that knew him, one of the most highly esteemed men of his time.

W. D. WEAVER.

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REMINISCENCES OF AN ELECTRICAL ENGINEER.*

By Horatio A. Foster.

A short time since a stuttering man was called upon to speak at a meeting of an engineering association, and when he got on his feet he remarked that he didn't quite understand why he had been selected to talk by the Chairman from about four million men endowed with normal talking faculties, and I might perhaps say the same thing of myself this evening. Worse yet, reminiscences mean the first person "I" all the way through, and I hope that I may be excused if the letter "I" appears more often than seemingly necessary.

In October, 1884, I joined the forces of the Daft Electric Motor Company of Jersey City and New York, thus starting my professional education. It may be interesting to learn the incident which led up to this. I had been at work with a railroad contractor in Eastern Pennsylvania as paymaster, bookkeeper, and incidentally, engineer, and having at this time subscribed to the *Springfield Republican,* as coming from near my old home in Massachusetts, I found one morning in the middle of the last page a short paragraph headed "New Occupation For Young Men—Electrical Engineer." As this was an entirely new occupation to me, and the first time I had ever seen or heard the combination "electrical engineer," I read the article with considerable interest and handed it over to my contractor friend at the breakfast table, saying that I should like to try that particular line of work. After reading the article he replied that nothing could be easier, as his partner had recently invested a considerable amount of money in the Daft Electric Motor Company, and no doubt he would take pleasure in introducing me to the officials of that corporation. This he did that forenoon with very considerable enthusiasm; and sometimes since I have thought that perhaps this enthusiasm was well-timed, as he may have wanted to get rid of me by placing me well elsewhere.

It would be difficult to explain to people and especially to the young electrical engineers of to-day, the routine and work that

* A paper presented at the 314th Meeting of the New York Electrical Society, held November 25, 1912, in the Engineering Societies Building, New York.

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one starting in the shop at that time was obliged to go through. This consisted of some winding of field-magnet coils, assisting in armature winding, machine testing, assembling. etc. I recall that the first job I was put on was to wind the field spools for a motor which was to be applied to a Sturtevant blower; and it so happened that these field coils had a ground in them somewhere which never was discovered, and though the motor was applied to the blower, it was used only around the factory and for exhibition purposes.

There being no schools at that date furnishing an electrical education, it became necessary to devise ways and means for studying the theory of electricity and, upon the advice of Mr. Daft, I purchased various books. I remember one was Kempe's "Telegraph Engineer," another was Gordon's "Electricity and Magnetism," and finally, much to the surprise and pleasure of every one, we found a book called Thompson's "Elementary Lessons in Electricity and Magnetism" which has continued to be in its numerous editions an important textbook. This together with work in the office or in testing and through talking with such few electrical engineers as there were at that time, comprised practically all the education that one could then acquire before going into the field.

Six months later, about the first of April, 1885, I was sent to Baltimore to equip a short line of existing street railway with electric power. There was no particular reason for picking me out for this purpose excepting that I had had a year's experience in railroad construction and knew something of grades and curves, weights of rails, dimensions of ties, etc. I am very glad to have it confirmed by Mr. Frank J. Sprague in a magazine article of some years ago that this road was the first commercially operated electric railway installed in the United States. Of course, there had previously been some experimental roads, such as that at a Fair in Toronto, and one, I believe, in Kansas City, but none of these remained in commercial use long, nor were they operated as commercial lines.

I believe that we had every accident and every bit of experience with the two motor cars with which this road was equipped, that could be possible with the longest road that might be built. A very considerable shop and shop force was necessary to keep

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it in running order and even then there was very little time when both of these motors were drawing cars over the track during the same period of the day. Mr. John K. Cowan, then chief counsel of the B. & O. Railroad and a director of the street railway company, spent some time almost every day looking over the work as it progressed; and after the road was in successful operation—that is, the motors moving and drawing cars, sometimes—he remarked that when Professor Rowland returned from Europe, where he had been during the summer, he was going to "rub it into him." It seems that just previous to starting the work, upon mentioning the fact that they were about to equip this line with electricity, the great Professor pooh-hooed the whole matter, and said that it was utterly impossible; and Mr. Cowan remarked that he did not think it was right for a man of Professor Rowland's standing to believe that there was anything that could not be done.

Another incident in connection with this road was the invention of the railway bond. Mr. Daft had devised a method of connecting the rails of the insulated track which we laid down but found it did not work. Strips of thin copper about an inch wide and seven or eight inches long were applied under the fish-plates after the contact surface of the rails had been brightened by filing. After squeezing this copper strip into place it was thought that the contact and connection would be good enough, but after the road was almost entirely bonded it was found that no current could be forced through the rails. Incidentally the old rails of the track had also to be bonded, and the same method was tried, but in all cases it was found entirely inoperative. One day in thinking over the matter someone in the shop—I am not sure whether it was myself or one of the young fellows around the place—remarked that a piece of copper riveted to the rail would probably do much better work. We immediately got some large copper wire, say about No. 1 B. & S., flattened out and rolled the ends, entered a quarter-inch copper rivet and put the whole into melted tin. Then a hole was drilled through the web of the rail with a rose bit which brightened the surface, the copper rivet driven into place and carefully riveted over. This sample was submitted to Mr. Daft, who immediately approved of it and sent us wire to bond the track and which was done as

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quickly as time would allow. One amusing incident took place in connection with this bonding and that was our attempt to connect the rails around the special work, that is, frogs, etc. For this purpose I had procured some inch lead pipe through which we put a couple of pieces of large, flat insulated wire and carefully tinned over the ends of the conductor, which projected beyond the ends of the pipe about six inches. Then the lead pipe was filled with melted paraffin, after which it was carefully laid in the earth alongside the piece of special work and the ends riveted to the web of the rails at either end. The first warm day that we had melted the paraffin out of the pipe and the pipe and copper were then allowed to lay as they were.

This road as planned by Mr. Daft was to be operated at a potential so low that it would hurt neither human being nor animals coming into contact with it at any point; but when it was attempted to operate the road with the voltage of one machine, this was found entirely inadequate and another dynamo was immediately installed and run in series with the first. We had no instruments for reading either the voltage or the current of these machines so that I never knew what potential the road was operated at nor the current flowing in the circuits. The current was turned on to the third rail during the afternoon at a time when there was a violent thunder storm, and a prize Jersey cow having a chain around her neck took occasion at this period to walk across the middle rail, which put an end to her existence in short order. This put a damper on the operation of the road during that afternoon, but current was again turned into the rails after midnight, when an attempt was made to operate one of the motors over the line which resulted in the motor halting when about a mile and half from the station. While we were attempting to get it started again someone came running up and advised us that a horse had fallen across the rails and died. This horse, I believe, was replaced by one worth about fifteen dollars a little later. Then it was determined to install guard rails along the track, and a force of men were put to work immediately placing four by four timbers on blocks parallel with the middle or insulated rail; at road crossings and places where it was necessary for teams to cross the track, the planks were raised considerably, those next to the rail being raised so

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that there was a distance of about four inches between the top of the rail and the top of the planking. Even with that horses with long toe calks would frequently get a touch of current and dance around a great deal. One morning about nine o'clock we heard shouting and very considerable profanity, and upon looking out at the crossing near the car barn, a horse hitched to a buggy was seen sitting on his haunches as a dog sits down, being unable to get on its feet; he too had touched the third rail.

About the first of November, 1885, I retired from the Daft Electric Company, and in August of the next year joined the forces of the Thomson-Houston Electric Company of Lynn, to become one of a long line of so-called experts connected with that company. The student courses in those days were not what they are at the present. The work then consisted principally of small filing jobs, the operation of a drill or some routine work on a lathe and various other little processes in a machine shop, the object being to make a man become more or less familiar with machine tools. Then they were put through the arc lamp work room, where they learned to put together the mechanism of an arc lamp, and from there they were transferred to the testing department and were taught the various tests and adjustments of an arc lamp. From this place they were sent to the dynamo room and instructed in the assembly and adjustment of the dynamo; and after this process, which took, in the ordinary course of events, some four or five months, the young man was sent out on the road to install electric lighting plants. But many of us didn't get the full five months in the shop and were sent out after an experience of anywhere from three weeks to three months, as orders came in so fast that some one had to be sent to install the machinery.

I was sent on two or three small jobs of erection of small plants and the re-adjustment of wiring, the last one of which was of considerable interest because it was the rewiring of a large factory in Central Massachusetts, which first opened my eyes for the necessity of insurance regulations for electrical work. This plant had been wired by an electrical contractor from Pittsburgh, and I should like to recall his name, because he was the first one that I ever heard of and incidentally about the worst; for after wiring this factory and installing the dynamos

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and calling upon Capt. Brophy to inspect the same, the Captain refused to permit it to be started, owing to the very careless manner in which the fuses had been applied. The owners of the plant, however, insisted that it be started and the moment the current was turned on several lamp cords burned to the ceiling, thereby exposing the manufacturing plant to grave danger from fire. The electric current having been turned off, word was sent to our firm at Boston to come up and put the plant into shape to operate, and I being the only man in the shop at the time, was given the job of putting the electrical circuits into condition to run. One can imagine the difficulties connected with this work, when I say that neither I nor any one around the factory knew how to calculate the size of wire for the different circuits, so that I merely replanned the work, as it was, running wires straight across the room at right angles instead of diagonally. This wireman had also put wires up in groups—that is to say, three No. 6 in the place of a wire of equal area, for some reason unknown to me; I removed these bunches and put in the one wire representing the same amount of copper and made the job look considerable better when done. I also placed fuse blocks at every point that I could discover where they seemed to be necessary, and for this I was very much complimented by Capt. Brophy, the insurance inspector, when he came back to go over the work for the second time. This work, I may say, was apparently successful and Capt. Brophy was my warm friend ever after.

About the first of February, 1887, I was sent to Maine as a salesman in that territory to take the place of an agent who was ill at the time. I had always had doubts about my ability in this line of work, and these doubts were eminently confirmed by the fact that while I was in Maine eight months I did not sell a single cent's worth of goods; but several years later the secretary of the Thomson-Houston Company remarked that he wished my successor had been as bad a salesman as I was, as none of the plants which he sold following my quitting the field was ever paid for. Early in October of the year 1887, feeling that my services as a salesman were hardly satisfactory, I obtained permission of the company to return to the factory with the idea of going into the electric railway department, which

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was then just starting, the first street car motor being under test the day I arrived at Lynn. I was told that they were going to put me in that department, but for a few days they wished me to get a little better acquainted with the alternating-current apparatus, which was at that time just coming out, and within three days I was sent to Philadelphia for a stay of three or four weeks, which resulted in my taking a position there as engineer for the Thomson-Houston Electric Light Company of Philadelphia for a year. In October, 1888, I was taken over by the East River Electric Light Company of New York City as Superintendent.

Returning for the moment to Lynn, a slight incident took place there such as influence the life of a young man, and that was my very temporary appointment as assistant superintendent of the works one day when the then assistant superintendent was ill, and after the superintendent himself had tried to do the work of both. This position lasted only three or four days, but served to put me in touch with all the operations of the factory and gave me the run of the works at any time after I got out into the field, and of which opportunity I took advantage by spending three or four days about once in three months going over the works and everything new that had come out in the meantime.

Among the little incidents during my work in Philadelphia was the following: At the West Philadelphia Cattle Yards there had been installed years previously one of the first types of Thomson-Houston dynamo that had been constructed, a machine of eight or ten lights in capacity. My attention was called to it from the fact that it would not generate current, and I was sent out to diagnose the case. About the first thing to look for at such times was open circuit, and I visited every lamp, climbed every pole and found nothing the matter with the lamps or circuits, and upon bringing a lamp back to the dynamo room and connecting it across the terminals, current was immediately generated. This showed that there was nothing the trouble with the dynamo itself, and a new search was then started for trouble on the wires, and it was finally found that the circuit was broken in a piece of molding running into the killing house and which had been corroded off by acids used in or about the place. Repairing this break, the circuits were immediately in order again.

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Another incident, this time at the Stetson Hat Factory, will show in a measure the feeling among the so-called electricians of that day. I was called to that point to examine the thirty-light arc dynamo, which would not generate current. In most of such cases, after finding that current could not be generated, it was customary to take down the front parts of the machine and remove and clean the running parts of the small pressure blower, which was one of the necessary and important pieces of apparatus attached to the Thomson-Houston arc dynamo. After getting the parts all off the machine and cleaning them, I sent for the chief engineer and asked him to stand by while I put everything back into position again, during which I explained its parts so that it would not be necessary for me to make another visit to the works for the same purpose; and after the machine was assembled and started up, current was generated at once. He then told me that he never had been permitted to see the assembly of any part of the dynamo, as the men sent up from the works to do the job always required every one to leave the room when they adjusted the commutator brushes and other parts. As I had met other people in the vicinity who said the same thing, I have every reason to believe it a fact that no one was permitted to witness the adjustment of a dynamo at that time; and afterwards I found that the men who were doing the adjustment knew absolutely nothing of the work, and only arrived at results by trial.

Another incident was the repair and adjustment of a small dynamo from the first tank steamer that came over from Scotland to Thurlow, Pa., to be loaded with kerosene oil and petroleum products. The fifty-light incandescent dynamo had refused to generate current within two days of leaving the Clyde. After putting it through various tests on the tank steamer, I had it removed to the works in Philadelphia where it was put in operating condition, the connections between the commutator and the armature being made whole—which was the whole secret of the trouble—and the original brushes replaced by new ones made of copper strip. After putting this in shape and starting it off, it was said that the light was very much better than it had ever been before. About two months later we received a telephone message one day from the captain of the same ship, which had

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made the voyage to Europe and returned, who asked us to send him another roll of the copper strip such as had been used to make those brushes. A couple of pairs of spare brushes and a roll of copper had been furnished with the repaired dynamo, and the expenditure of these brushes and a roll of copper in a month's time is of some interest as showing the quality of dynamos in those days.

During my stay at Philadelphia I was sent to Camp's shipyard one day to look over the plans, models, and operation of the ships then building for the government with the idea of determining what kind of dynamos could be furnished for electrical service on those ships. I believe the boats were the "Vesuvius" and "Baltimore" and models were shown me of both of them and plans showing the dynamo rooms, which, I may remark, seemed to me to be nothing but closets, and a small pamphlet giving specifications for the electrical equipment was supplied to me. I read this going home on the street car and upon my arrival at the office told our manager that we could not make any bid for the reason that there was not a bit of wire made in the United States that would satisfy the specifications, nor was there a dynamo built in this country which would come anywhere near filling the specified requirements. It is unnecessary to say that no bid was offered at that time, but the Edison Company designed a dynamo for the purpose, as did the Brush Company, neither of which was successful. Then the Thomson-Houston Company designed a steam engine which would operate under the naval specifications and also a dynamo that could be operated in connection with this engine, and I think at the time there was not a single engine built other than this that would operate under the specifications as written by the Navy Department; and I may add that the Bishop Gutta Percha Company immediately started the manufacture of rubber-covered wire which would fulfill the naval requirements.

The East River Electric Light Company with which I became connected early in October, 1888, was installed in an old sugar refinery at the foot of East Twenty-fourth Street, New York City. This refinery had not been in operation for some eighteen years, but there was a full equipment of water-tube boilers very

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much after the style and type of the Babcock & Wilcox boiler of the present day, and one old engine in a corner of the building which afterwards served to preserve a franchise. There was installed in the central portion of the large main building a beautiful tandem compound Corliss engine of about four hundred horse-power, which was afterwards stretched to some eight hundred horse-power, and upon the next story above was placed a long line of shafting operated by belt from the large compound engine, and the dynamos were belted off of this line shaft. This was the method of operating most of the large stations of those days, and has only gone out of use since the advent of direct-connected units. This plant had been installed through the efforts of some of the politicians in New York City, who had obtained the right to run all of the company's circuits upon the telephone and telegraph poles then infesting the city of New York, and furthermore, on all poles of the other lighting companies as well.

An incident connected with one of the politicians behind all of the movement may be of interest. He was in the habit of coming to the works at about nine or half-past every morning and would come into my office, which was about eight feet square and had a roll top desk in it, carefully close the door, then lean over the desk as if to tell me something of momentous importance and say "Good morning." I never could quite understand this, but supposed that it must have arisen from his political education, which was certainly the only education he ever had had; but he was a very bright fellow and very much of a gentleman.

I think this large compound engine was one of the very earliest installed by an electric light company, and it certainly did very good work at the East River Electric Light Station; and its adjustment was such that indicator cards could be taken from its cylinders which were so perfect that people would seldom believe that they were taken directly from an engine.

Somewhere about 1890 and soon after his Honor, Hugh J. Grant, was elected mayor, which made him ex-officio chairman of what was than the Board of Electrical Control, he called a meeting to which he invited the managers of all the electric light plants, and there announced that the next Monday work would begin cutting down poles and removing wires from the central

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portion of the city commencing at seven o'clock in the morning, and starting on the pole at the southeast corner of Fourteenth Street and University Place, working north on Broadway as far as they could that day, and continuing the work through the selected region in the best manner that suggested itself. As this thing had been threatened and tried time and again and injunctions had been fought out in all cases—the city winning every one of them—the managers did little but laugh at the mayor for making the statement; but when a big lineman climbed the designated pole right after seven o'clock Monday morning and with his pliers cut all the wires leading North therefrom, there being sixty or eighty of them, consternation was in the camps of the electric light companies. Before the week was out there was not a plant in operation in the city of New York except the Edison Company whose wires—as you all know—were underground. The gas companies were called to put tips and burners on the street lamps, and the city of New York returned to street illumination by gas jets. Previous to this time everyone had declared that it was utterly impossible to operate arc light wires in the subways. The Consolidated Telegraph and Electrical Subway Company had constructed conduits covering most of the central portion of the city, and had for two or three years endeavored to induce the electric light companies to place their wires therein, and this incident of cutting down the overhead wires was the culminating act which forced them to make use of the conduits. Of course everyone was in a hurry to get in, and various new ways of installing circuits were evolved at the time. I recall one employing a rubber tube constructed of hard rubber but quite flexible; the twisted wire cable was pushed through this and then the whole was installed in the subway. This cable lasted for a short time only.

The Standard Underground Cable Company put down some of its well-known cables which also worked fairly well, but the rubber covered cables were the only ones which, at the time, gave any really satisfactory results. There were one or two new cable companies organized for constructing these cables, and in a year or two some one built a plant for covering copper wire with strips of paper which was then soaked in oil, and covered with lead, and

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this cable is the one which has been in use most commonly and with perhaps the greatest satisfaction of any of the cables that have of yet been installed, and is besides very considerably cheaper than the rubber covered variety.

An incident relative to alternating currents will, I am sure, be of interest. At that date, 1889 and 1890, I may say that no one knew the theory or correct practice for the measurement of alternating currents, as at that time such a thing as a power factor had never been heard of outside of the laboratory; so when I was called upon to make a test of the electric light stations at East River and at Yonkers, we applied indicators to the engines, weighed the coal and water, and made the usual steam test of the steam power end of the station, at the same time measuring the current and voltage of both the direct current arc light circuits, and the alternating current circuits; then the watts and kilowatts were determined from the electrical data by the usual method of multiplication, and of course we got a very beautiful test of the efficiency of the station and one which was highly satisfactory to all hands. If I had ever heard of a power factor at that time I believe I should have hesitated to apply it, but we certainly were proud of the results of our two tests. In connection with this I will relate a little incident which took place at the World's Fair, Chicago, 1893. I had discovered a very nicely designed motor, evidentally built for alternating currents, in the exhibit of the General Electric Company, and was told that it had been designed by the Fort Wayne Electric Company. I then went to the Fort Wayne exhibit and asked their engineers some questions regarding the motor. They said that it was a mighty pretty machine to look at, but actually worth little, as it took as much power to drive it unloaded as it did loaded, which showed me that in 1893 there were still people who were unacquainted with power factor.

About 1890 the manager of the East River Company became interested in a plant in Harrisburg, Pa., and discovering a small water power existing in the heart of that town at one of the locks of the Pennsylvania Canal, got permission to utilize this to drive a new central station which he purposed building at that point. A pipe was laid in the bank of the canal running from the upper

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side of the lock to the lower, and one or two turbines aggregating about two hundred horse-power were installed at the lower end of this tube—the fall being approximately twelve feet. With these water wheels were operated a line shaft running through the basement of the building, the dynamos on the floor above being placed to the right and left of the shaft. A large vertical compound condensing engine was installed at one side of this line shaft, and a pulley on a quill constructed over the shaft was equipped with a jaw clutch which served to connect the quill and shaft when throwing the engine on to the load. This is not in use to-day, but the method of connecting in the jaw clutch with which this mechanism was equipped, which method was devised by an old millwright who designed the water power end of the plant, may be of interest to the youngsters. A light was placed on one side of the clutch, a window serving for this purpose in the daytime. One then looked through the space between the revolving parts of the clutch, and when the shadow seen there waving back and forth came to a stand, the jaws could be thrown together easily.

The East River Plant was equipped with the first Moran boiler, which was built outside of the Lorillard Tobacco Factory, Mr. Moran being the chief engineer of that plant. The old boilers with which the sugar house was equipped had stood idle for some eight or ten years and deteriorated to an extent as to be of little use, there being only two or three of them in which steam could be maintained with any pressure. Thus the installation of further steam capacity became necessary and a contract was made with the company building the Moran boilers for a boiler of five hundred horse-power, which was installed in fifteen days and nights and proved to be a great producer of steam at all times. Later our manager, being of the progressive type, replaced all of the old boilers with others of the Manning type—a vertical boiler with which some of you may be familiar, which is used considerably in factories in New England and in an improved form is a boiler of very successful design.

In connection with the operation of electric lighting plants at that date—that is to say, say twenty-three years ago—there are some little incidents which may be of interest to the present gen-

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eration, and among them I will relate one or two. Young men sent from the factory to install electric light plants were then seldom engineers in any sense, but they were nevertheless successful in plant installation and especially in getting things going, which they always managed to do in some way or other. For instance, I recall one plant in Vermont which was to be started upon a certain day or the franchise would lapse; the young man who was building it announced that it would be started on time, but discovering on the last day that he had not wire enough to complete his line, he finished one side of the circuit with wire and for the other side used the track of a railroad passing the plant, and the lights were lighted that night. Another incident was connected with the circuits of the Mt. Morris Electric Light Company, which had a station at 125th Street and another one way downtown with circuits connecting both stations. During one evening when a circuit was in trouble, they discovered that one side only was affected between certain limits in the city, and they immediately cut off that portion of the wire which was in trouble and connected the remaining ends of the circuits to another wire running uptown; this wire belonged to some other company, but it closed their circuits and enabled them to keep the light going.

In July, 1891, I was appointed electrical expert for the United States Census office and the census of 1890 was the first one in which electricity was mentioned in any way whatsoever. Mr. Allan R. Foote—then the secretary of the National Electric Light Association—was appointed special agent in charge of electricity in the census office, and had spent much time and money compiling report blanks covering all of the business of that date. These report blanks were very comprehensive indeed and covered the electrical business of that date quite as thoroughly as anything of the kind has since done; but in doing this so much time and money had been expended that it was resolved not to make a census of the electrical business of the whole country but only for the city of New York, and I was asked to take the position of travelling expert to collect the data connected with the electric light stations in the state of New York. This I did, making a visit to every electric light station in the state and visiting also

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nearly all of the isolated plants then in operation. This took from the middle of July, 1891, until the first of August the next year, at which date I went to Washington and compiled the data which I had previously collected in the field. The result of this work was published in a small pamphlet which was available for a long time to anybody asking for the same, but was printed so late in the day that every one had forgotten that an electrical census had been taken, and I think was of no use except as a starter for the electrical census of later times which has been so ably managed by Mr. T. C. Martin, who tells me he has made very considerable use of this small pamphlet.

On May 2, 1892, I was appointed editor of an electrical journal published in Chicago, known as *Electrical Industries,* and acted as its editor during the Fair which I visited nearly every day. This was a very valuable experience both in seeing the Fair and getting connected with the writing end of the business, and I have been told since that my work on that journal was very much appreciated at the time. But hard times came along during that summer and everybody had to retrench and I was looking for another job.

One incident which will be of interest perhaps, and especially to those present who are connected with the Institute. is the fact that an attempt was made during the World's Fair to start branches of the American Institute of Electrical Engineers at different parts of the United States. I recall the meeting very well, which took place in Mr. Ralph W. Pope's office of the Institute of Electrical Engineers in the electricity building, and especially the presence of Mr. William Henry Preece, later Sir William Preece, who took an active and interesting part in the meeting, but deprecated very much the idea and advised devoting all money that could be expended to the printing of papers and books. The idea languished for about ten years, when Philadelphia undertook to establish a branch of the Institute, and now as you well know there are many of them in very successful operation.

In September of that year having severed my connection with editorial work, I became associated with Professor George Forbes, F. R. S., M. I. C. E., who was at that time the electrical

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engineer in charge at Niagara Falls of the work of the Niagara Falls Power Company, then beginning the first installation of the very large power plant now in operation at that point. Right here I wish to credit Professor Forbes with being one of the ablest theoretical engineers that I have ever been associated with, and who at that time was at the very least ten years ahead of all the electrical engineers in the theory of alternating currents. Everything which he designed—that is, in his mind, for he never was allowed to design it further than that—has since been worked out in practice and has been found to work with the greatest possible success. In fact, his first design or idea for the dynamos at Niagara Falls was to build them for a pressure of ten thousand volts which would entirely eliminate the use of transformers at that point for many years, but which plan was pooh-poohed by all of the electrical manufacturers of the day, who said that it was utterly impossible to insulate for that purpose. He was thus forced to allow the manufacturers who built the first dynamo for the Falls to employ such a potential as they thought it was safe to design for, and which resulted in the use of the pressure of twenty-two hundred volts as the standard pressure for many of the large power stations of that time and to-day.

Incidentally it may be said that when the first bids were sent in for five thousand horse power dynamos for Niagara Falls, there was not a single bid which in any way paid any attention to the specification which had been supplied to the bidders, notwithstanding that there were two or three points which it was positively necessary to be observed as they had been determined by the engineers who were designing and building the water turbines. One requirement, for instance, was 250 revolutions, another, weight on shaft not to exceed eighty thousand pounds, and another—to enable the water wheel designers to obtaining guaranteed results in speed—was that the fly wheel effect should be eleven hundred million pounds. With the exception of the revolutions, 250, none of the bidders paid any attention to any of the other points, and it was necessary to throw out all of the bids. Professor Forbes then returned to England and designed the type of machine many of you have noticed at Niagara Falls, having the umbrella form of outside revolving field. The dynamo which

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Professor Forbes worked out had many new points of design, especially that of the revolving field; the fact that it was outside the armature was merely for increased fly wheel effect necessary for governing of the water wheels. But some points about the designs were so unsatisfactory to the American manufacturers that they all refused to bid. The Professor then told the companies to use their own shop experience in the details of the design and work out one which they believed would operate, but to observe the three fundamental points in the specifications, namely, revolutions, total weight of revolving part, and fly wheel effect. When the successful design was turned over by the Westinghouse Company it was found that the weight was within six hundred pounds of the limit, and the fly wheel effect was a good hundred million pounds over and above that specified.

When Professor Forbes left the service of the Company, I became connected in an incidental way with these works, and was asked by Mr. Edward D. Adams, then president of the Cataract Construction Company, to specify a test for the then very large dynamos. I wrote a very careful one, which he then asked me to apply, and I went to the Westinghouse Factory at Pittsburgh, where I made the final test of the third machine turned out under the first contract. The next summer I spent almost the entire time with Mr. Stillwell, then chief engineer of the Westinghouse Electric and Manufacturing Company, making the power-house tests at Niagara Falls. These, as you may imagine, were very interesting indeed as being the first made of the very large machines which since have been used in very considerable numbers although of much different type.

Soon after the Company began supplying power from these works I was asked to visit the Carmelite Monastery on the Canadian side of Niagara Falls, where I had the pleasure of meeting Father Kreidt who, the day I visited him, was in consultation with his architect for the building of a new monastery upon the hill overlooking the Falls. The reverend father told me that in view of the great water power of the Falls it seemed to him that they ought to be able to have all cooling, lighting and heating and other service in the monastery performed by electricity furnished by the falling water. I told him that it would take

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very little current to supply their mechanical wants but I was a little bit afraid of the cost of heating the place; and as I now recall the figures that I assembled then, there were but fifteen horsepower necessary for mechanical work while six hundred horsepower would be required for heating. This put rather a damper on the matter for a time, but after somewhat reducing their requirements, I have understood that since then the entire place has been supplied with heat, in addition to all its requirements for lighting and power, from current generated at the Falls.

A word about overhead guard wires may be interesting. When the pole line was built between Niagara Falls and Buffalo, for some reason which I have since been unable to explain, I was instrumental in getting three guard wires of ordinary barbed fence wire installed on the type of the line; that is, one wire was installed on a pin as the top of the poles and two others were placed upon iron pins about fourteen inches high at the ends of the top cross arm, and the whole three wires were connected and grounded at about every third pole. During that summer I recall that there was a very great deal of lightning in that region, and in fact so much of it that it was almost possible to read by its light, but not once was that line struck by electricity. During the next winter those wires began to rust and to break; and since, as you may know, a piece of barbed wire will always return to the shape it had when wound on its reel, the breaking and curling of these wires led to such frequent line short circuits that the managers had all of them removed from the poles, and I am not acquainted with the results since then so far as they refer to lightning.

During this time the question of price to be charged for current from Niagara Falls came up, and I was detailed by the Company to make many and various tests of steam power for determining the actual commercial cost of such power in order to obtain data upon which they could base the price to be charged to their prospective customers. I spent about a year and a half at this work testing many mills in Fall River, the large plant of the Carnegie Steel Company at Homestead, and plants of various kinds in the vicinity of Niagara Falls and Buffalo. The results of these tests were afterwards embodied in a paper which was read before one of the meetings of the American Institute of Electrical Engineers,

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and reprinted in pamphlet form. During these tests I discovered many of the idiosyncrasies of stationary engineers which, while they may be known to some of you, I am sure are not known to all. The ten plants which I tested in Fall River were all equipped with steam engine indicators, but in only one or two plants were these instruments in condition to use. In many of them the points had a very great deal of play, in others the pencil arm was loose, and all of them had cylinders which were practically inoperative. A year or two before my visit to Fall River a law had been passed in Massachussetts requiring all stationary engineers to be examined by a board of engineers at Boston for a license to practice, and in the city of Fall River, while there must have been seventy-five engineers operating the fifty large cotton plants at that point, there was but one man who had a first-class license; and it may be mentioned that the board of examiners had to amend their rules so as to permit an engineer who had successfully operated a steam plant for a certain term of years to retain his position by a special license good only for that plant.

An incident in connection with the paralleling of machines at the Niagara Falls power house may be of interest. At the time these machines were built it was decided that they must be run in parallel, but as no alternating machines had been normally thus operated up to this time, after the first two or three machines were put in operation every one hesitated to make the first move. In fact, the first time that two of the machines were put into parallel it was by accident; no one knew how it was done and every one was much worried as to how they were to be taken apart. It resulted in shutting down both of the machines simultaneously by stopping the water wheels. I recall at about that time the visit of a very noted English engineer. who, in showing him over the plant, asked if the machines were designed to be operated in parallel; and when I told him "yes," but that we had not at that time worked out the method of connecting them together, he predicted considerable trouble when it was tried.

Up to this point in my career I had been working for other people and with other people to guide me and advise me, but during my work making the steam tests I began to acquire a very considerable amount of self-confidence and an incident connected

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with this will show how confidence is at times thrust upon one. I had made a test of one of the mills of Buffalo, which had resulted in a very considerable saving of fuel, and the owner thereupon became one of my best friends and most prominent client. One day I received a message to call at a certain office, where I found assembled a number of directors who announced that they had received bids for a water works pump and desired me to tell them which was the one which they should adopt; and that, all other things being equal, they should like very much to have a local concern receive the award. I told them that I would report the next day at the same hour. I then called in the bidders one at a time and asked him to explain his bid and go over it just as if I knew nothing about the business, and as a result received enough information that day to make me an expert in the water works pump business. Upon the following morning I informed the people that there was but one pump that had been offered that would fulfill their specifications and that pump was not built by the company to which they wished the bid awarded. They then asked if there was any way that he could have a chance, and in reply I said only by throwing out all the bids and re-writing the specifications. I may add that the man did get the job finally and furnished a first-class pump, but at a price so low that I doubt whether there was any profit to his company.

About this time, 1895, I made my first valuation of a public utility property, that of the Chicago Edison Company, preparing a report upon the property for an English syndicate. The whole work of this valuation was done in thirty days, but I should dislike very much to have to stand by that valuation today. In the year 1896 I began serious work upon the "Electrical Engineer's Pocket Book" bearing my name and continued this until it was published in 1901. It may be interesting to relate how it is that so many of the technical books now published have adopted the method of contributors. When the manager of the Van Nostrand Company took up the matter with me he said, "How do I know that you know anything about electricity." I said that was quite a valid question, and that if he didn't mind we would adopt the principle of submitting each and every chapter as I produced it to some man who was an expert upon the par-

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ticular subject covered by that chapter. This was done and in most cases chapters were submitted not only to one but to two, three and four people. This enabled us to make use of the names of these revisers and contributors, and since the time of the issue of this book, it has probably been noticed that many others of a similar kind have been written and compiled in the same manner.

About this time—1900—having considerable more business in Philadelphia than I had in Buffalo and vicinity, I removed my office to that city where I was engaged for six years in business as consulting engineer and incidentally as federal receiver of a brewery trust which had failed and of which I was receiver for one and a half years, and president for four and a half years, only leaving it to get back into engineering at a time when the brewery business was in first-class condition, the plant in successful operation, and the engineering work with which I became connected was large enough to warrant my severing connection with the brewery interests. Incidentally I may say that during my connection with the brewery I didn't drink a glass of beer. It may be quite difficult for some of you to believe this, but I can assure you it is a fact, although in telling this incident almost everyone remarks that I probably knew what the beer was made of. It was a fact that we made good beer and I can say with little chance of contradiction that it is about as cheap to make good beer as it is to make poor beer, therefore leaving little excuse for the manufacture of anything but good beer.

An incident at this time in connection with the Susquehanna Power Company will I am sure, be of interest in showing that engineers are called in to do things rather unexpected. One day I was telephoned to go to Conowingo, Md., which is a station on the Susquehanna River a few miles northwest of Perryville, where I met several lawyers, and a Sheriff's jury together with a number of other gentlemen. It seems that they were all assembled to condemn some land on both sides of the river for a proposed new power company to be established at Conowingo. The land belonged to the McCall Ferry Power Co., which had built a plant ten miles further up and just over the Pennsylvania

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line. I sat around with this sheriff and jury for several days and finally when I asked what I was there for, the lawyers on our side said they didn't know but that they had been asked to call me in on the case. I sat around and listened to the evidence until one day the lawyers on our side began to ask what price they should set on the land. Then it occurred to me that perhaps I might work out a price by starting at the last sale. This had been made by the then Chief Engineer of the proposed new plant, who with two other associates had owned all the land on both sides of the river up as far as the McCall Ferry Plant, and had sold it to that company for $40,000 in bonds and some $225,000 stock of the McCall Ferry Company. The question now arose as to what division could be made of these bonds and stock as between the land on both sides of the river, and I asked the former owner to get out his bills. In going over these we determined what he had paid for the various parcels of land along both shores of the river, and thus we were enabled to divide the bonds and stocks as between the two sides; and upon placing this before the attorneys the next morning, they all rejoiced that some one had been able to determine what they should ask or offer for the land. I here testified, not as a real estate expert, but as a plain engineer, as to those figures, but later after the whole case was brought before the orphans court at Bellaire, Md., I testified as a real estate expert, and was qualified as such real estate expert; and as this qualification has never been taken from me, I therefore can say that besides being an electrical engineer, I am a real estate expert.

In 1906, leaving the brewery business, I became associated with L. B. Stillwell of New York, in charge of his work at Baltimore, where we rebuilt many of the power stations and put in good operating order all the others. Thus twenty-one years after I had installed at that point the first commercially operated electric railway in the United States I returned to re-design all the power plants connected with the railway. During the fall of 1907 and the winter of 1908 I purchased for the Railway Company $250,000 worth of copper at almost the highest price paid in the market, viz., 27 cents. It may be remarked that the price of copper at that time and during the previous year had been very influential in our building a power station at Bay Shore nine miles from

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the center of the town, rather than constructing a substation at that point connected with the high tension circuits; for the installation of enough copper to furnish the power at that point from the low tension side of the circuit would have been so costly that we built a new station and equipped it with engines and boilers taken from older plants in the city.

After the Baltimore work was completed I returned to New York and became associated with Mr. B. J. Arnold in his valuation of the railways in New York City for the Public Service Commission, and have devoted very much of my time since that date to this class of work. My first job was the valuation of the property of the Metropolitan Street Railway which afforded some difficulties for engineers, but brought out many new points and demonstrated to my satisfaction that the properties of the railways in New York City cost so much in real cash expenditure that far from being a mint, as formerly thought, there was little chance for other than a small return on the money expended. In April, 1909, I was detailed by Mr. Arnold to appraise the properties of the Detroit United Railways, and at that point spent a little more than a year working out this valuation and later, while still associated with him, I spent about six weeks in Pittsburgh working out the probable cost and prospective earnings of the nucleus of the subway at that point, learning to our own satisfaction if not to that of the promoters, that if the money for the building of this subway was furnished by outsiders at the rate of six per cent., it would take them over forty years to get out from under a deficit; this for the reason that like most all other cities, there was not a sufficient population closely adjacent to the surburban end of the line, and therefore that until many more flats or apartment houses were built adjacent to the far end of the line, it would not be a successful operating proposition. In July of 1910, still associated with Mr. Arnold, I went to Los Angeles to appraise the property of the Southern California Edison Company, a company whose property extends over a territory about two hundred miles long and seventy-five miles wide along the Pacific Coast. They light some twenty-seven different towns, and have a property which is not only very

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valuable but of special interest to an engineer from the variety of the work which it performs.

One or two incidents in connection with the one hundred and ten-mile transmission line from Kern River to Los Angeles may be interesting. On the large steel towers over which their transmission line is built, the many eagles at that point are wont to retire to rest at night on the cross-arms; in the morning when they awake and stretch their wings, they frequently close the circuit between the wires, which immediately burns off and shuts down the power and incidentally sets fire to the eagle which in dropping, in turn sets fire to the dried grass along the line, which results in a forest fire. Some of the incidents and difficulties attending the building of such a long line will doubtless be of interest as showing some of the unexpected costs always turning up on such work. At the time that the transmission line was nearly finished and the Company was in very much of a hurry for power, one evening six or seven burros were each loaded with two of the large insulators used on this line, and driven into the mountains to close one of the last gaps remaining. Something, however, frightened the burros on their journey and in their antics they broke all but three of the insulators. Another incident was the burying of a man in the high pressure main at the Kern River Power Plant. In some way unknown to any one in charge, a man got buried in the stone and debris in the tunnel running from the works down to the power station, and was only discovered by his tapping on the rails of the track which ran down into this tunnel. The men on the outside were able to thrust a pipe through and under the debris along the channel of one of the rails, and through this pipe he talked and was fed with milk, until he could be dug out.

Since my return to New York from Los Angeles, I have been connected with J. G. White & Company and have made the valuation of public utilities a specialty, recent work being in Winnipeg, Manitoba, and also a study of traffic conditions in Toronto.

I think that the length of this lecture has probably begun to tire you, and therefore, thanking you for your attention, I bid you good-night.

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GRAND CENTRAL TERMINAL OF THE NEW YORK CENTRAL LINES, NEW YORK CITY.*

By Carl Schwartz.

The development of New York Central terminals dates back to 1832, when the first passenger station was built by the New York & Harlem Railroad Company on Center Street, close to City Hall. In 1857 a new station was erected at 26th Street and 4th Avenue, where Madison Square Garden stands at the present time. In 1871 this station was abandoned for the use of the first Grand Central Station which up to two years ago (having been enlarged in 1900) occupied the present site of the main building of the new terminal.

The New York Central Lines operate to-day over 13,000 miles of railroad in the territory between New York, Boston, Montreal, Buffalo, Chicago, Cincinnati, and St. Louis, serving more than two-thirds of the population of the whole United States. The railroad company has in service at the present time 4,541 locomotives, 4,684 passenger coaches and 237,600 freight cars. The number of passengers carried during the year 1911 exceeded 85,000,000 and the freight was in excess of 221,000,000 tons. The average number of employees during this time was 159,000.

Coming back to the terminal proper, a few figures illustrating its magnitude may be of interest. The main building covers an area 300 feet wide and 720 feet long at the street level. Below the street level the station is 445 feet wide and 745 feet long. The entire terminal extends from 42nd Street South to 57th Street north and from Lexington Avenue east to Vanderbilt and Madison Avenues west, a total area of 47 acres. The amount of rock and dirt excavated for the terminal amounts to 3,000,000 cubic yards and the total cubical contents of all buildings will approximate 1,000,000,000 cubic feet. The traffic handled at the present time amounts to about 600 incoming or outgoing trains per day.

Some unusual features of convenience of the Grand Central Terminal are the elimination of stairways, which is accomplished

* The New York Electrical Society held its 318th meeting December 19, 1912, at the New Grand Central Terminal, New York City, where the members were shown the more interesting features of this structure through the courtesy of Mr. Carl Schwartz.

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by the use of ramps, or inclined ways, thus providing for the movement of vast crowds from point to point without confusion.

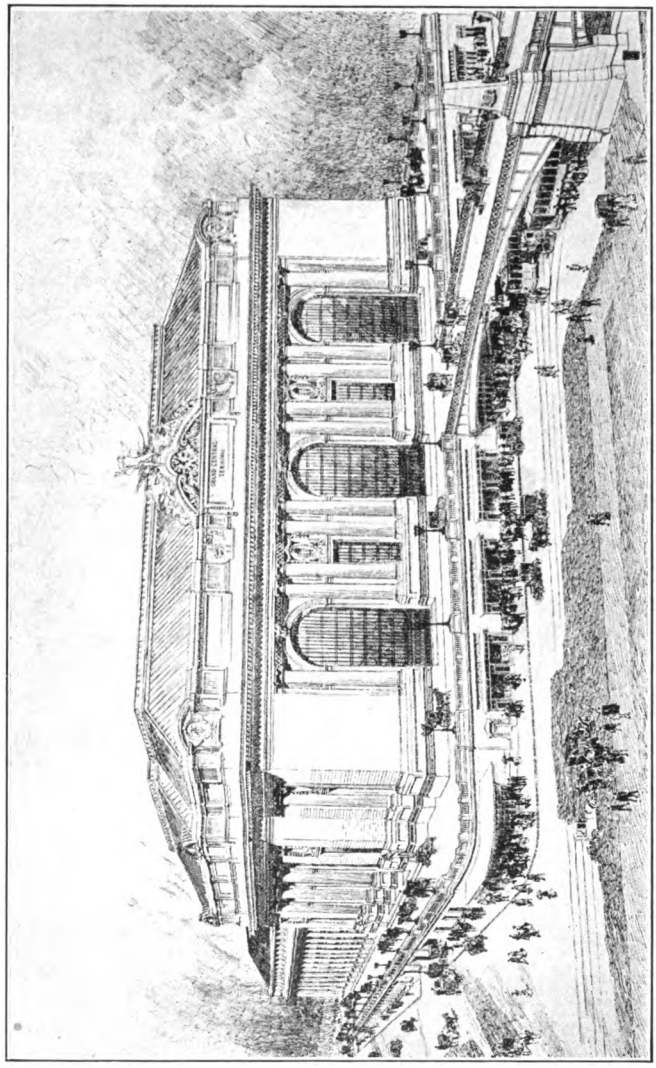

Fig. 1.—Grand Central Terminal, Forty-Second Street and Park Avenue.

This is an arrangement greatly superior to stairways, which introduce an element of danger when traversed by large crowds.

All these inclined ways are located in direct lines of traffic, so that the immense crowd that moves to and fro will never have to

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turn any corners or in any way retrace their steps. In other words, to handle the thousands that at times sweep back and

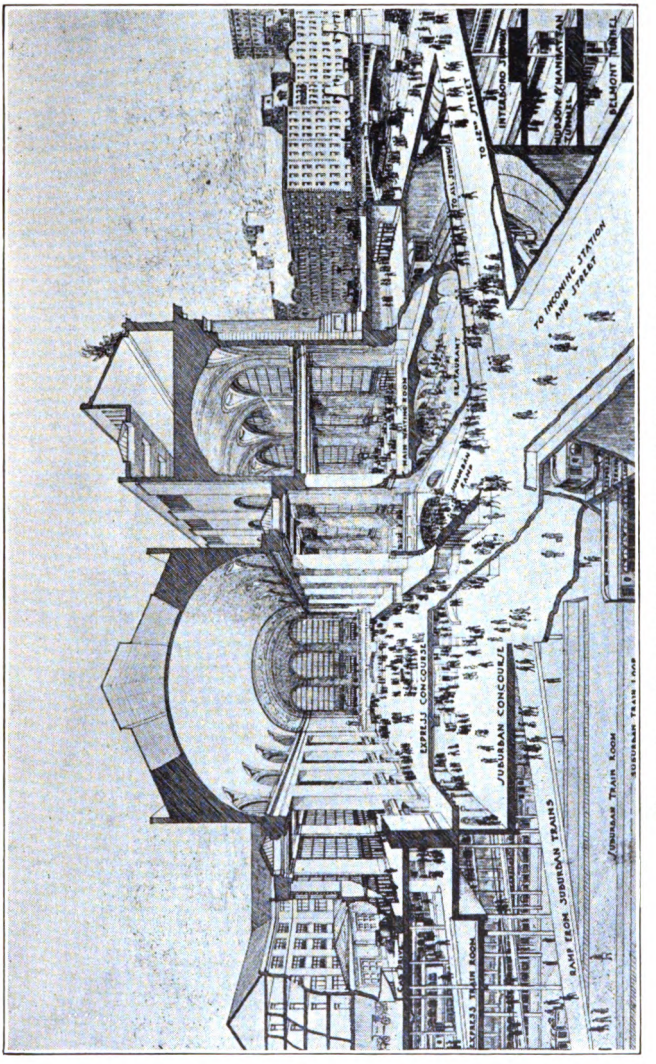

Fig. 2.—Cross Section Showing Ramps and Absence of Stairways.

forth through this gateway, everything is arranged to avoid all possible friction or confusion. It will not be necessary to teach people where they should go; they will naturally move in the right direction.

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Another feature is the complete segregation of through and local inbound and outbound traffic. This is accomplished by

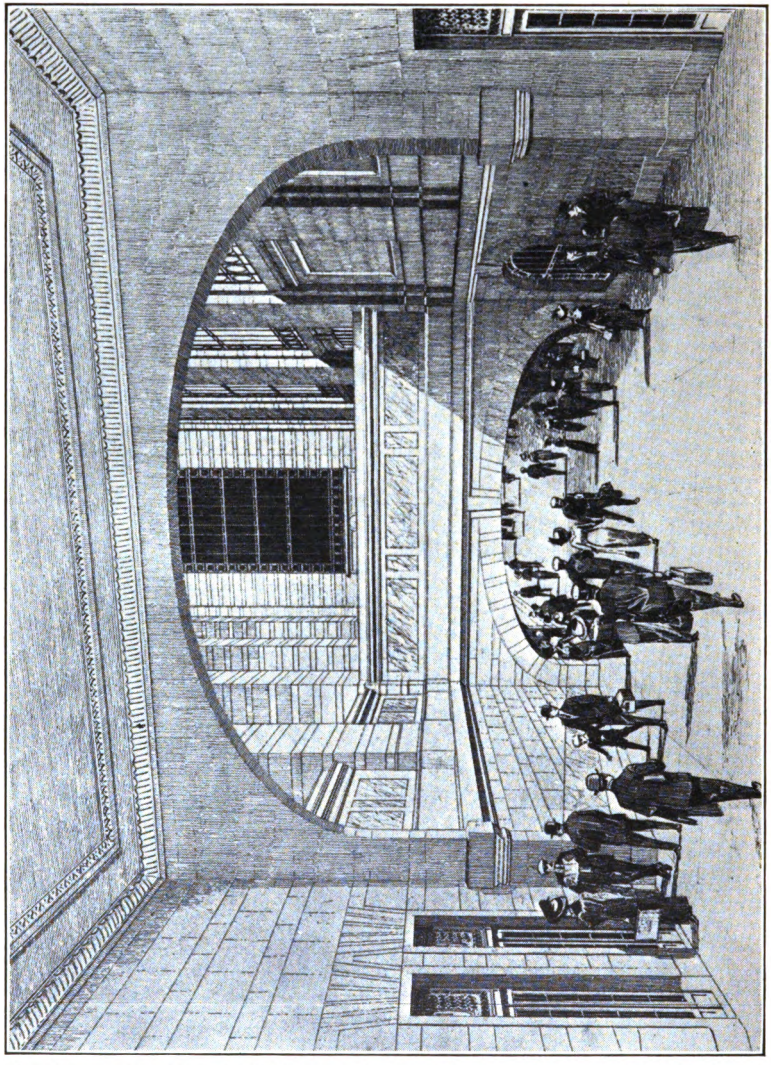

Fig. 3.—Incline Walk from Subway to Suburban Concourse.

having separate waiting rooms and concourses for local and through passengers; and a separate station for the incoming traffic eliminates completely all counter currents of travel and the confusion resulting therefrom.

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The tracks are arranged on two levels, the upper for through business, the lower for local, and both having loop tracks

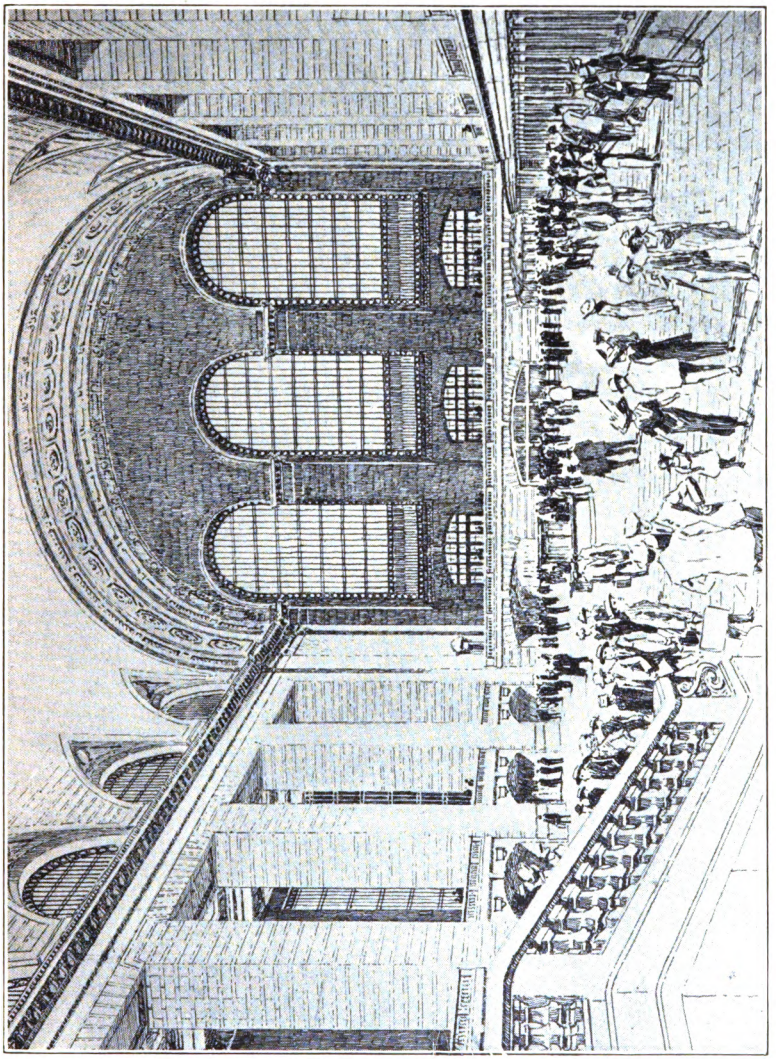

Fig. 4.—Outbound Concourse.

which circle under the main building. After the passengers are unloaded the trains are taken around the loop and the baggage cars shunted to special baggage tracks for unloading; the train then proceeds to the storage yard, or, if a local train scheduled

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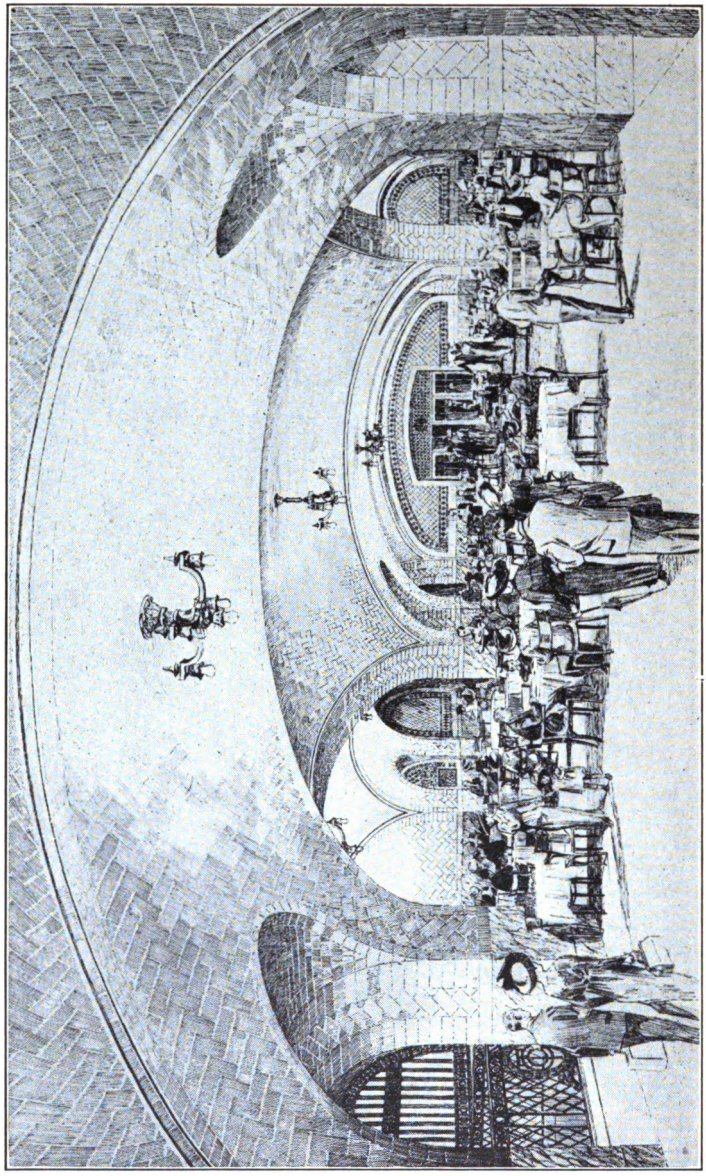

Fig. 5.—The Restaurant.

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to leave within a short time, it is placed adjacent to one of the outgoing train platforms, ready to receive passengers again.

It is interesting to note in this connection that in establishing the various levels of the terminal, the main concourse floor was built on a level with the mezzanine, or ticket-office floor of the subway, as it was found that about eighty per cent. of the people arriving at and departing from the terminal use the subway to complete their journey. The level of the concourse floor being established, the other levels were worked out with that as a basis.

The Grand Central Terminal is the center of a most extensive combination of passenger transportation lines. On 42nd Street there will be, with the completion of the Belmont Tunnel to Long Island, the Hudson and Manhattan Tunnels to New Jersey and the Lexington Avenue Subway, four great arteries of local transit, including the present Interborough Subway, having direct subsurface connection with both the outgoing and incoming stations of Grand Central Terminal. In addition, electric surface lines radiating in all directions, pass the door, *i.e.*, the Madison, Fourth and Lexington Avenue Lines, 42nd Street and Broadway line and the line to Long Island City via Queensboro Bridge.

The New York Central Lines are engaged in an undertaking vastly greater than the building of a railroad terminal alone. To build a terminal, the best that could be devised was the primary thought, but along with that as the plans were developed came the larger thought of the utilization of the property over the yards for building purposes. This is the most original and in many respects the most distinctive phase of the development, and it has called into being a beautiful civic center, of which not only the citizens of New York but of the entire country, may well feel proud. The tracks were depressed below the street level, and Park Avenue and the cross streets from 45th Street to 56th Street were built in, thus reclaiming about twenty city blocks and throwing the entire area open for building purposes. Contract in your mind's eye a steam and smoke-filled railroad yard with blocks of handsome commercial buildings, office structures, hotels, apartment houses and club houses, all of harmonious architectural design, and you will have some conception of what a transformation is taking place. It is probably the largest

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and promises to be the most successful, combination of the aesthetic and practical in city building.

Where other idealistic group plans have failed or remained incomplete, because dependent upon appropriations by the city, this one will succeed because of its earning power. The property over the railroad yards when leased will turn in a large revenue and help to pay interest on the large amount of capital involved in the terminal and correlated improvements.

A point worthy of note in this connection is the great increase in the value of realty on 42nd Street and Park, Madison and Lexington Avenues, of property abutting the terminal but not owned by the railroad company. The elimination of smoky railroad yards, opening of streets where none existed before and the rearing of beautiful buildings, have had a wonderful effect on the character of the surrounding territory. To what extent in millions of dollars the property owners in this section have been benefited by the comprehensive improvements made and projected, it would be difficult to compute. And it should not be forgotten that the whole city, all taxpayers and the rent payers, who in the final analysis pay the taxes, are benefited. The increase in value means that this section will pay an increased share of the city's expenses.

Electrical engineers and men identified in some way or other with electrical engineering, have the gratification of knowing that the development of the terminal in its present form has only been made possible by the substitution of electrical traction for steam motive power.

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New York Electrical Society

THE purpose of the New York Electrical Society, founded in 1881, is to present in popular but none the less authoritative form, the latest advances in the electrical and allied sciences and arts, and to encourage professional and social relations among its members. All persons in good repute and interested in electricity and its applications, are eligible to membership.

Upon request, an application blank and list of members will be forwarded by the Secretary. When returned filled in with the name, address and occupation of the applicant, and with endorsement by two members of the Society, the application, upon approval by the Examining Committee, will be presented for action at one of the regular meetings of the Society.

The entrance fee is $1.00, and the annual dues, $3.00.

GEORGE H. GUY, Secretary, Engineering Societies Building,
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NEW SERIES 1913 NO. 3

Transactions

of the

New York Electrical Society

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PHOTOGRAPHY BY INVISIBLE LIGHT

BY

Dr. R. W. Wood

Professor of Experimental Physics,
Johns Hopkins University

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TRANSACTIONS

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NEW SERIES 1913 NO. 3

PHOTOGRAPHY BY INVISIBLE LIGHT.*

By Dr. R. W. Wood, LL.D., Professor of Experimental Physics, Johns Hopkins University.

The experiments to which I shall draw your attention this evening have been carried out with a view of ascertaining whether the employment of invisible light in our study of natural phenomena will materially add to our knowledge.

A very large part of our discoveries in all branches of science have been made by eye observation alone, without the aid of optical or other apparatus. The eye is, however, sensitive to only a very small part of the total radiation which reaches it, and it seems not unlikely that, if its range could be extended, many new phenomena would immediately come to light. By the employment of photography and of instruments which detect and measure the intensity of the infra-red or heat rays, much new information has been gathered, especially in the science of spectroscopy; but usually these methods have been applied only in cases where the invisible radiations were known to be present. It seemed quite probable that if photographic methods were applied to various physical phenomena which excluded the action of any but invisible rays, new facts would probably be discovered. I can illustrate what I mean by taking two striking cases which were found at the very outset of the investigation, and which will be more fully discussed presently.

* A lecture delivered at the 316th Meeting of the New York Electrical Society, held January 30, 1913, in the Engineering Societies' Building, New York.

The TRANSACTIONS are indebted to the courtesy of the Smithsonian Institution, Washington, D. C., for the engravings used in this report of the lecture.

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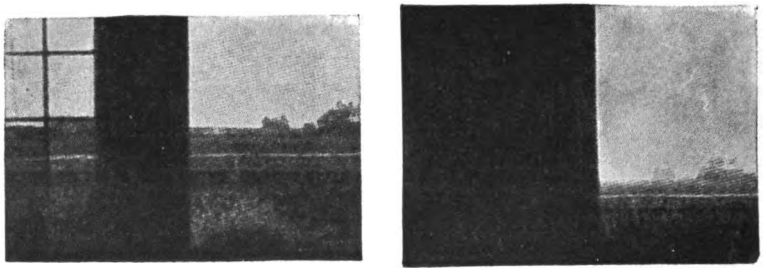
If the finger be dipped into powdered zinc oxide, and rubbed over a sheet of white paper, eye observation is absolutely unable to detect the presence of the streaks made by the white powder, unless it has been very thickly applied. If, however, we photograph the paper with ultra-violet light we obtain a picture in which the streaks are as black as if made with powdered charcoal. This suggests that if we apply the process to the photography of the moon and planets, we have some reason to suspect that substances which cannot be detected visually may come out in the photographs, a surmise which has been justified in one case at least. This and other similar cases will be taken up in detail presently.

Glass is absolutely opaque to the ultra-violet rays, which have been used in the present work; consequently a lens of quartz must be used in the camera, and in addition we must have a ray filter which cuts off the visible light while transmitting the invisible rays. A thin filter of silver deposited upon the lens answers the purpose.



Visible Light. Ultra-Violet Light.

Fig. 1.

We will next take up the action of our atmosphere on these ultra-violet rays. I have taken two photographs of a man standing in the road in full sunshine, in the one case by ordinary light and in the other by ultra-violet radiation. In the latter the shadow is completely absent. Ultra-violet behaves in exactly the opposite way to the infra-red. The infra-red rays are enabled to drive through the atmosphere without being scattered laterally by the molecules of the air or the dust particles. The short or ultra-violet rays, on the other hand, are completely scattered, so that the greater part of the ultra-violet light which reaches the

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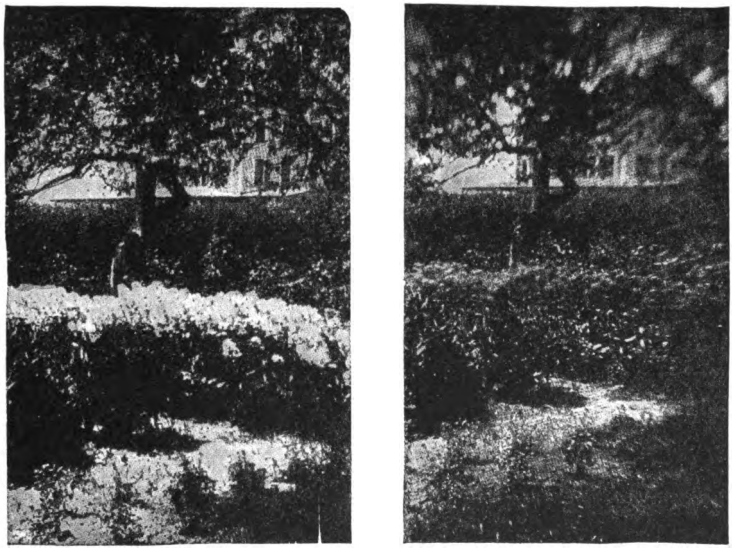
surface of the earth comes from the sky and not directly from the sun. If our eyes were sensitive only to ultra-violet we should find the world appearing not greatly different from the aspect which obtains at the time of light fog. We should, indeed, see the sun, but it would be very dull, and there would be no shadows, just as there are none on a foggy day. We should walk the earth like Peter Schlemeil, the shadowless man of the German fable.

The opacity of ordinary window glass to ultra-violet radiation is illustrated in Fig. 1. It will be noticed that there is no trace of the landscape seen through the glass window, although it is



Visible Light. Ultra-Violet Light.

Fig. 2.

clearly rendered in the companion picture taken with visible light. Another difference to be noted in these pictures is that the flowers in the garden, which are white in the picture taken with visible light, disappear entirely in the picture taken by means of the ultra-violet radiation. The white garden flowers become almost black, as is shown in Fig. 2, which shows white phlox photographed by visible and ultra-violet light. It occurred to me that this ability of the white flowers to absorb the ultra-violet rays might play some economic part in the growth of the plant. I therefore experimented with some flowers which had been grown

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under glass, and had thus been deprived of ultra-violet, but I was unable to find any marked difference between those which had been grown in the open and others which had been deprived of their full quota of this radiation. It is possible that if the experiments were carried on through the course of a number of generations, we should find a difference. I have found, however, that all white flowers are not equally dark when photographed with ultra-violet light. White geraniums, for example, come out much lighter than common white phlox, which is practically black when photographed through the silvered quartz lens.

In order to demonstrate the difference in the appearance of one of the common pigments when viewed respectively with visible light and with ultra-violet radiation, some letters were painted in Chinese white on a page of a magazine. In the photograph (Fig. 3) taken with visible light the Chinese white appears

Visible Light. Ultra-Violet Light.

Fig. 3.

as white as the paper itself, if not indeed whiter; but, photographed with the ultra-violet radiation, it comes out absolutely black. One may say that what is Chinese white in visible light becomes Japan black in ultra-violet. Under this radiation also black printer's ink becomes lighter than in visible light. In working with my Chinese white I made a mistake in one letter in the word "appears," and carefully wiped it out, leaving no trace of the correction discernible in visible light but when the photograph was made with the ultra-violet, the erasure, otherwise visible, showed as a black smudge. The ultra-violet camera is evi-

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dently very much more sensitive than the eye to the presence of traces of Chinese white on the printed page, for so far as I could see, every particle of the pigment had been removed.

This property which ultra-violet light has of bringing out invisible stains I have recently applied to the detection of erasures made by chemical means on documents such as wills and contracts. A check which had been raised from twenty-four dollars to twenty-four hundred by an expert, so skilfully that it passed the scrutiny of a bank cashier, when photographed by ultra-violet light showed a black smudge over the word "hundred" where the chemical ink eraser had been applied to remove the ink line drawn across the face of the check after the "twenty-four." Still more recently, in photographing a contract in which it was claimed that erasures had been made subsequent to the signing, I have succeeded in bringing out some of the erased words.

I shall now illustrate in a striking manner the opacity of glass to the rays. Here we have a microscope under a transparent bell jar of glass standing in front of a sheet of white paper and illuminated by the light of a Cooper-Hewitt mercury arc burning in a quartz tube. Close to it are a number of incandescent lamp bulbs in white porcelain sockets. When we employ ultra-violet light, the microscope has disappeared, the glass bell appearing as black as sheet iron, and casting a coal-black shadow.

Another class of work in which this comparative study is likely to be of service is the photography of heavenly bodies. For the full moon the exposure through the silver screen was two minutes with ultra-violet light belonging to the region 3,000 to 3,200. It will be seen at once (Fig. 4) that there is very little difference between the ordinary image of the moon and the one which is shown us by the ultra-violet radiation. Nevertheless, in the neighborhood of Aristarchus, which is the brightest crater on the lunar surface, the photograph taken with the ultra-violet rays shows a dark patch which is absent on the one taken with visible light. I made an enlargement of the region in which this crater appears, and it is evident that there is in its neighborhood a large deposit of some material which can be brought out only by means of the ultra-violet. These photographs of the moon make it appear extremely probable that by carrying on experiments of

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this nature on a larger scale we might get a good deal of new

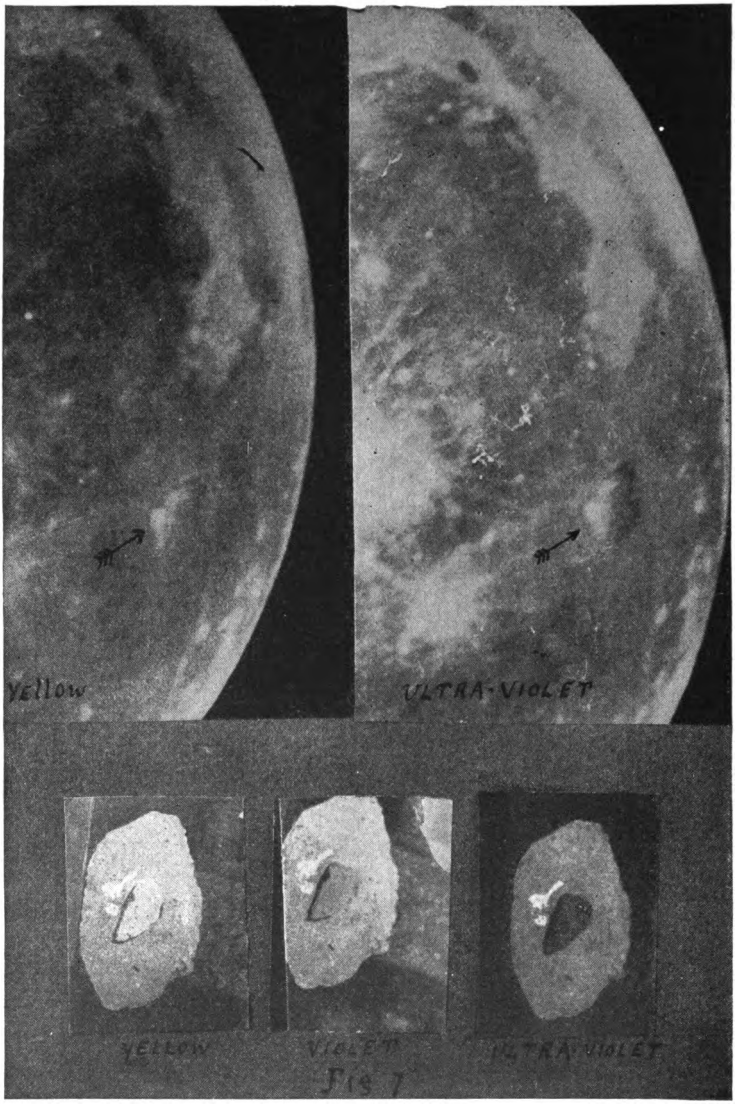

Fig. 4.—The Moon Photographed with Invisible Light.

information as to the materials of which the moon is composed. It is possible to examine the igneous rocks of the earth under

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the different radiations, and then compare them with the pictures of celestial objects obtained at the same wave-lengths. I have found that some rocks, which when illuminated by ultra-violet rays appear darker than others, are lighter than the others in visible light.

I have recently had constructed a 16-inch mirror of 26-feet focus which I have coated with nickel, for extending the study of the ultra-violet photography of the moon and planets. This is now being used in combination with a plate of the new ultra-violet glass, 12 cm. square and 1 mm. thick, heavily silvered. The plate was made by Zeiss, and I find that it is quite as transparent as quartz for the rays transmitted by the silver filter. This reflector was mounted on the 23-inch equatorial of Princeton University, and some very fair pictures have been obtained, though the moon's motion in declination could not be followed with sufficient accuracy to secure the best results. Fig. 4 shows two views of the region around Aristarchus (indicated by an arrow), one made with yellow, the other with ultra-violet light. The dark deposit to the right of the bright crater comes out very clearly in the latter. The markings to the right of this region are quite different in the two pictures. Immediately below the pictures of the moon are three photographs made of two samples of volcanic "tuff" arranged one upon the other, with the crater Aristarchus marked with white chalk (as a check upon the exposure). The left-hand picture was made with yellow light, and the central specimen is lighter than the one surrounding it. The right-hand one was made with ultra-violet, and shows the central specimen distinctly darker. The middle picture was taken with violet light, which shows the two specimens of very nearly the same luminosity. I made an analysis of the fragment of tuff, which photographed dark in ultra-violet light, and found that it contained iron and traces of sulphur. Photographs of rocks stained with iron oxide did not show the required peculiarity, and I accordingly attributed the result to the sulphur. A light deposit of sulphur was formed on the surface of a piece of light-grey rock by directing a fine jet of sulphur vapor against it. The deposit was so slight that absolutely no trace of it could be detected by the eye. The specimen was then photographed with yellow, violet, and ultra-violet light, and it was found that the

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deposit was quite invisible in the first picture, faintly visible in the second, and quite black in the third—precisely the peculiarity shown by the deposit surrounding the crater Aristarchus. Fig. 5, *a, b, c,* show the gradual appearance of the deposit, which is an oval spot in the center of the specimen. I feel inclined, therefore, to attribute this spot to an extensive deposit of sulphur, resulting from vapor ejected from the crater. The shape and vast extent of the deposit has always suggested to me that it resulted from material driven out in a volcanic blast.

I have recently invented a source of light which emits ultra-violet light of such spectral purity that it is even possible to photograph the metallic vapor rising from a drop of mercury.

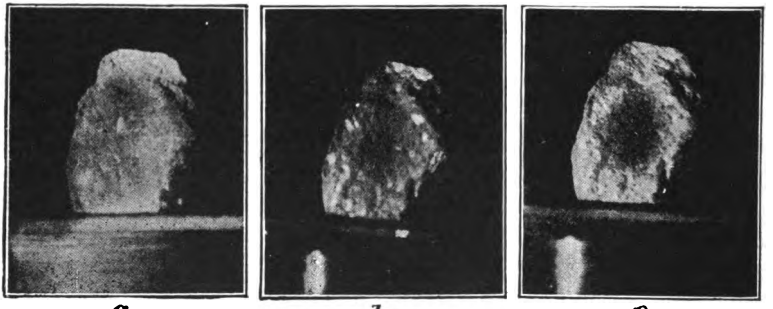

Fig. 5.—Deposit of Sulphur on Rock Surface.

The vapor of mercury exhibits an absorption band in the ultra-violet region which resembles the band at wave-length 5,893 shown by dense sodium vapor. So powerful is this absorption that I have detected it in the vapor of mercury at room temperature. It occurred to me that this light instead of being absorbed might possibly be re-emitted by the vapor laterally in all directions. To test this point I sealed up a drop of mercury in an exhausted flask of quartz, and focused the light of the mercury arc (burning in a silica tube) at the center of the bulb, which was not heated. The bulb was then photographed with a quartz lens, and the picture clearly showed the cone of focused rays precisely as if the bulb were filled with smoke. This is another very good example of how new discoveries may be made by ultra-violet photography.

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The bulb of mercury vapor illuminated in this way constituted the source of ultra-violet light alluded to above, and has been named the "Resonance lamp."

Another interesting line of investigation which I have recently carried out, illustrates how new discoveries may be made by the aid of ultra-violet photography. It occurred to me that the air surrounding an electric spark might possibly be rendered fluorescent by the absorption of the very short ultra-violet waves discovered by Schumann, but that the fluorescence might be made up wholly of ultra-violet light and consequently invisible. I therefore photographed the region surrounding a powerful spark discharge with a quartz lens, shielded from the direct light of the spark by a circular disc. The photograph, when developed, showed a highly luminous aureole surrounding the spark and extending out in all directions to a distance of nearly 2 cm. It was now necessary to prove that this was not light scattered by the dust particles in the air. To do this we have only to photograph the spectrum of the aureole. If it is similar to the spectrum of the spark, we are safe in attributing it to scattered light. If it differs we know that it must be fluorescence, or the genesis of waves of different wave-length from any present in the light of the spark. A photograph of the region surrounding the spark was made with a quartz spectrograph, and it was at once found that the spectrum was wholly different from that of the spark, in fact, it was almost identical with that of the oxy-hydrogen flame. For the further study of the phenomenon, a piece of apparatus was devised by which the light of the spark could be more effectually shut off. A small hole was bored through a plate of aluminium fastened to the end of a short vertical brass tube. This plate formed one electrode, the spark passing between an aluminium rod lying along the axis of the tube, and the under side of the plate at the point perforated by the hole.

In a perfectly dark room, if the eye was held a little below the plane of the plate, no luminosity could be seen in the air above the hole, if it was reasonably free from dust, yet a photograph taken with a quartz lens showed a bright beam, or squirt, of light issuing from the hole. A photograph of the phenomenon is here shown, and you will notice the strong resemblance which it bears to a comet (Fig. 6).

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Many weeks have been spent in an attempt to determine the exact origin of this radiation, and the question has proved to be the most baffling one which I have ever attempted to solve. The work is still in progress, and many remarkable observations have been made, each one leaving us more in the dark than before.

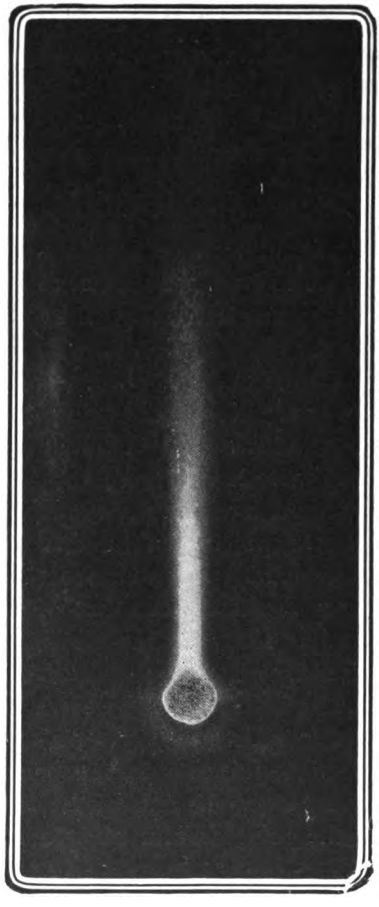

Fig. 6.—Experiment with Invisible Light.

As an illustration I may mention a circumstance discovered by Dr. Hemsalech and myself last winter in Paris. We found that if a jet of air was blown through the squirt of light the luminosity was destroyed in the region traversed by the moving

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current of air, but was of undiminished intensity both above and below this region. This makes it seem as if the emanation

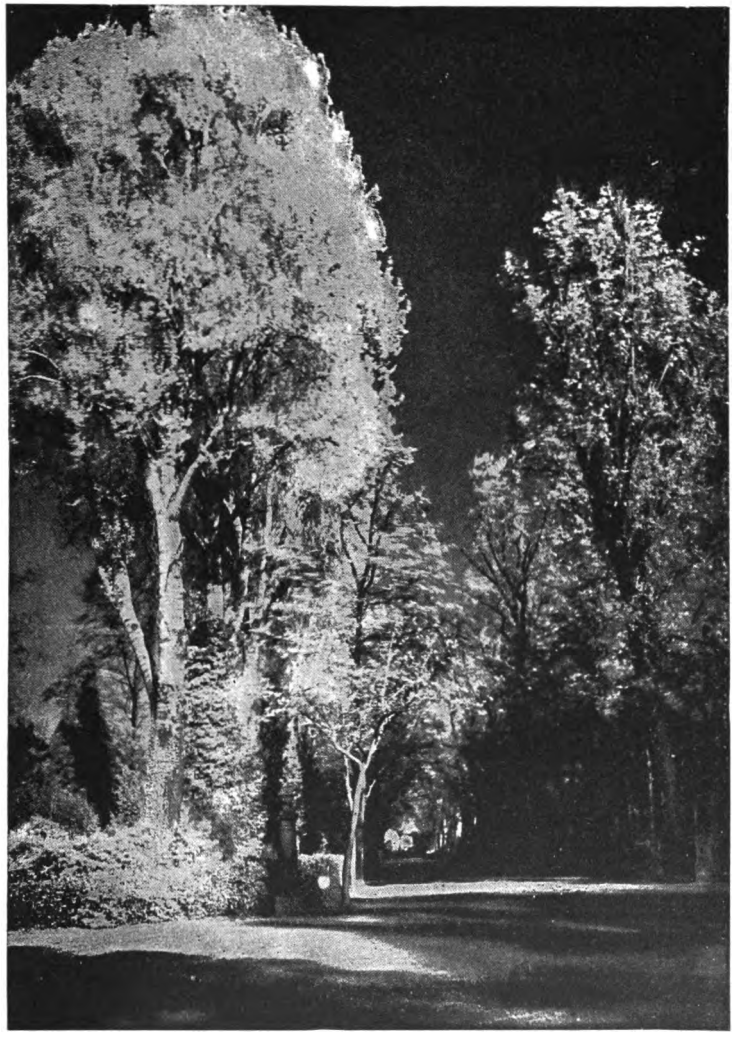

Fig. 7.—Park in Florence. Photographed by Infra-Red Rays.

which comes from the spark, and which causes the luminosity of the air, must act for a brief time upon the air in order to cause the luminosity. It also shows that the emanation, whatever

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may be its nature, is not swept aside by the air current. We have

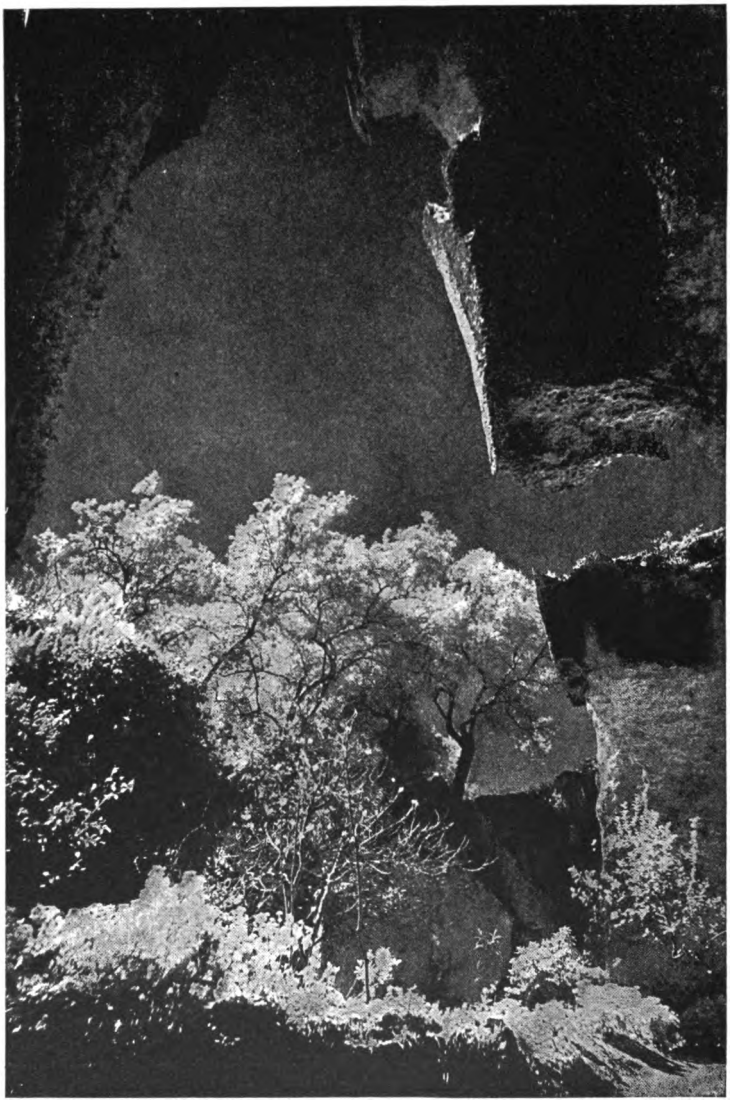

Fig. 8.—Quarry in Syracuse. Photographed by Infra-Red Rays.

also found that other gases become luminous when subjected to the spark emanations, the spectrum in each case being different

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and peculiar to the gas used, electrolytic hydrogen, for example, giving a strong luminosity.

It is thus apparent that by employing this "photographic eye" of quartz many new phenomena may be brought to light which have previously hidden themselves behind the limitations of the human eye.

Curious results have been obtained by photographing landscapes with the invisible rays at the other end of the spectrum, the infra-red rays. We can use an ordinary camera lens for this work, and a ray filter made of a combination of a saturated solution of bichromate of potash and a strong solution of cyanine. If the screen is properly made, green leaves in full sunlight against a clear blue sky should appear coral red against a black sky, and a photograph taken on a Cramer spectrum plate will show the sky dead black and the trees as white as if covered with newly-fallen snow.

The photographs reproduced in Figs. 7 and 8 were taken through such a screen, with the spectrum plates made by Wratten and Wainwright. Fig. 7 was made in the park at Florence, Italy, and shows the long drive overshadowed by trees, the one in the foreground being particularly fine in appearance. Fig. 8 was made at the bottom of one of the old quarries at Syracuse, Sicily, the view looking out through a cave-like formation at a group of almond trees, with which the quarry is overgrown. The time of exposure was about three minutes in full sunlight, with the lens stop set at $f/8$. The views have a very curious appearance, for while the sky comes out in all of them almost as black as midnight, the foliage of the trees and the grass come out snow white. This peculiar effect results from the failure of the atmosphere to scatter these long rays. The green leaves, however, reflect them very powerfully, or more correctly, transmit them, since we are dealing with pigment or transmission color. If we look at a landscape through the screen, carefully protecting the eye from all extraneous light with a black cloth, we shall find that the trees shine with a beautiful rich red light against a black sky. This condition obtains only on very clear days, for the presence of the least haze in the air enables it to scatter the long rays, and you will notice that in those pictures which show the sky down to the horizon, there is a progressive increase in its luminosity

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as we pass from the zenith downwards, as a result of the greater thickness of the mass of air sending the scattered rays to the camera.

Another point to be noticed is the intense blackness of the shadows in the infra-red pictures, due to the fact that most of the light comes directly from the sun and little or none from the sky, which reminds one forcibly of the conditions which obtain on the moon, where there is no atmosphere at all to form a luminous sky.

In the case of photographs made with ultra-violet light, we have the conditions reversed, for practically all of these very short waves are scattered by the atmosphere, and we have no shadows even in full sunlight.

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Transactions

of the

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The William J. Hammer Historical Collection of Incandescent Lamps

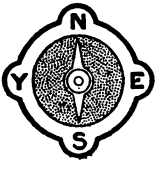
BY

William J. Hammer

The Pollak-Virag Rapid Telegraph

BY

Antoine Pollak



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An Organization for the Dissemination of the Knowledge of Electricity and its Applied and Allied Arts, and for the Promotion of Social Relations among its Members.

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TRANSACTIONS

OF THE

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NEW SERIES 1913 NO. 4

THE WILLIAM J. HAMMER HISTORICAL COLLECTION OF INCANDESCENT ELECTRIC LAMPS.*

By William J. Hammer.

It will be impossible for me to do even scant justice to the history of the incandescent electric lamp in the brief period assigned to me to address you in this evening. The informal remarks, for I have no notes, which I shall make to you this evening will be largely confined to the "History of an Art," which you will be able to inspect later on the tenth floor of this building in the headquarters of the American Institute of Electrical Engineers. I have been engaged upon this work for about 34 years. I trust that when we later arrive upstairs, you will not hesitate to ask any questions and I will endeavor to answer them to the best of my ability.

It seems essential at the outset of my remarks upon this collection to say at least something regarding the genesis of the incandescent electric lamp. While Mr. Thomas Alva Edison is universally recognized as the father of the commercial incandescent electric lamp, it is nevertheless a fact that there were incandescent electric lamps made long before Mr. Edison's time; yes, even before he was born.

* A lecture delivered at the 317th Meeting of the New York Electrical Society, held February 17, 1913, in the Engineering Societies Building, New York.

The magnificient collection of incandescent electric lamps formed by Mr. Hammer during the past thirty-four years, and comprising over 1,000 specimens, has been secured by the Association of Edison Illuminating Companies and is appropriately housed in a room in the Engineering Societies Building, New York. The lamps are skilfully arranged in five large glass cases for convenient inspection by visitors, each lamp being accompanied by a descriptive card.

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In the year 1910 Sir Humphrey Davy, at the Royal Institution in London, with his famous battery of 2,000 cells and his pieces of willow charcoal, formed a 4-inch electric bow or "arc" and this experiment laid the foundation for all subsequent "arc" lighting systems. It is interesting to note that he was also the founder of incandescent electric lighting, as he at this early period made both platinum and carbon incandescent by means of his famous battery. After describing his experiments with the arc light, he says, "And a platinum wire 1/30 of an inch in thickness and 18 inches long, placed in circuit between the bars of copper, instantly became red hot, then white hot, and the brilliancy of the light was insupportable to the eye."

The first English patent on the incandescent electric lamp was that of De Moleyns in 1841. He proposed to sprinkle finely divided carbon or graphite over the surface of an incandescent platinum wire.

Mr. J. W. Starr, a young man from Cincinnati, Ohio, a protege of the well known philanthropist Peabody, in 1845 took out a patent, through his English attorney, King, in whose name the patent appears, for a lamp consisting of a strip of graphite in a Torricellian vacuum. It is very interesting to note that in the year of his death 1847 (the very year, by the way, in which Mr. Edison was born) Starr had the privilege of exhibiting before the immortal Faraday a chandelier, or electrolier, of 26 of these lamps, representing the 26 states which constituted the Union at that time.

In 1858 Gardner and Blossom took out the first American patent in this field, it being for a platinum lamp to be used for a railway signal lamp. One of these lamps may be seen to-day in the Patent Office Museum at Washington, D. C.

Many men subsequently contributed to the Art, among those of an early period being Konn, Kosloff, Bouliguine, Lodyguine, Changy, Staite, Fontaine, Draper, Adams, Watson, Farmer, Roberts, Sawyer, Maxim, and others; and it is but right that we should keep these names green in our memory because their work was work of importance, even though it did not directly result in the establishment of the commercial incandescent electric lamp.

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There were inherent defects in all of these lamps; they were nearly all separable lamps. Some burned in the open air, and others were sealed by glass or porcelain plates and, if exhausted, probably possessed only a Torricellian vacuum. Torricelli discovered that mercury in a glass tube at sea level would stand at a height of 30 inches when a glass tube so filled was inverted and stood upright in a vessel of mercury. Starr and others utilized a tube 6 or 8 inches longer than this, filling the entire tube with mercury, so that when the tube was inverted, as already described, the mercury would fall until it reached the height of 30 inches, leaving a Torricellian vacuum above this vacuous space being utilized by some of the early inventors for their electric lamps.

The early platinum lamps were very limited in their possibilities; for if platinum is brought up to over 3 to 4 candles, its melting point is reached and it softens like butter. Edison's first lamp was a platinum lamp, but he alloyed iridium with the platinum, as had been done by Staite before him and the use of which had been still earlier suggested by Petrie. Edison found that by gradually heating the wire by means of an electric current, then allowing it to cool, and reheating and cooling it again many times, he was enabled to drive out the hydrogen gas which was occluded in the pores of the metal, and the metal became exceedingly dense and so hard that the sharpest file would not affect it. It was like a new metal, and a spiral coil, which had a radiating surface of 3 sq. in., could be raised to from 30 to 35 candle-power without melting. A thermostatic wire placed in the center of this spiral was attached to a short-circuiting lever, so that an excess of current sent through the spiral would heat and expand this thermostatic wire, allowing its lever to touch a contact which short-circuited the spiral. As soon as the spiral had cooled, sufficiently, the thermostatic wire would lift the lever, thus throwing the spiral back into circuit again. This lamp was known as Edison's platinum-iridium thermostatic regulating lamp.

In this early work of Mr. Edison's of 1877-1878, he not only employed platinum in the form of wire and foil and alloyed it with various metals, but he did considerable work with various metallic oxides and you will note among his early lamps his

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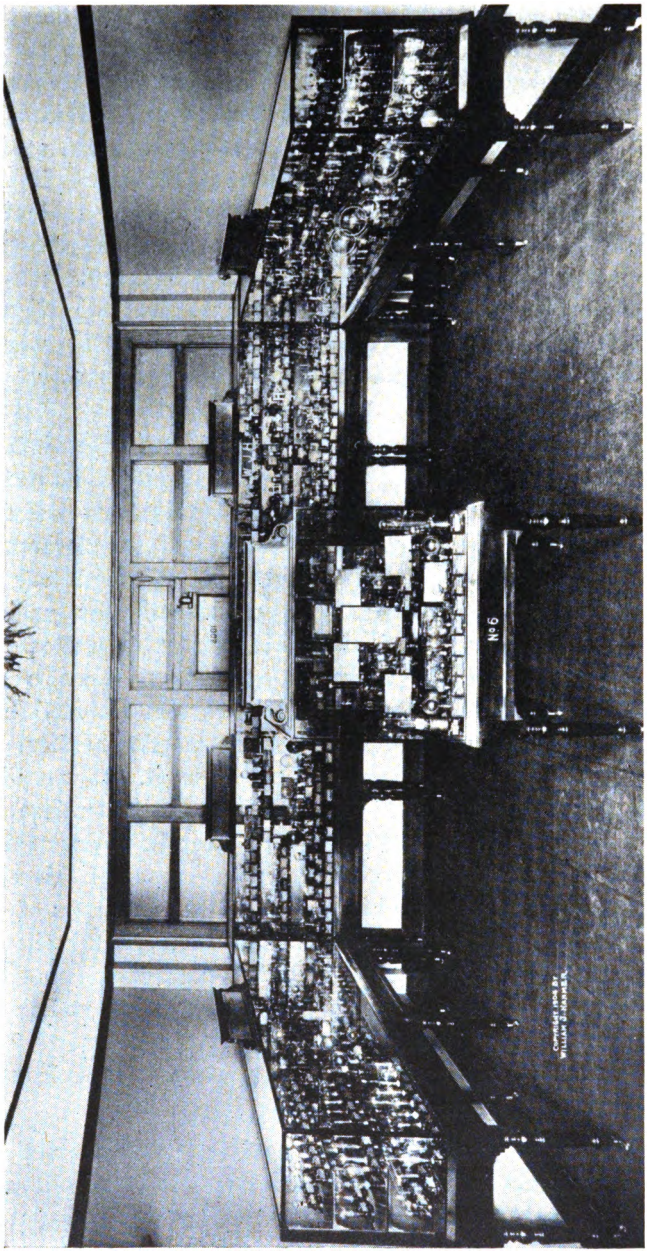

Fig. 1.—General View of Incandescent Lamp Collection.

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oxide of zirconium lamp; another lamp shows a platinum wire coated with titanium oxide.

In 1879 Edison's famous "paper horse shoe" lamp appeared, this being his first thoroughly commercial lamp, and of which 700 or 800 were installed in the Edison laboratory and workshops, dwelling houses and through the streets at Menlo Park, N. J. The filament of this lamp was cut out of a piece of bristol board, which in carbonizing shrunk about one-third in size. Lamp filaments were also made of thread rolled in tar; also from graphite and of many kinds of vegetable fibers, such as manila, hemp, bast, jute, bamboo, etc.

You will observe that the historical incandescent lamp collection is contained in five cases, four of which are ten feet in length. They are of plate glass with glass shelves and with mirrors at the back. In addition to these four cases, there is a fifth in the center, which is four feet square. The brass plates on the cases are numbered from 1 to 5 and give the periods of the Art covered by the lamps contained in each case and the names of certain of the inventors.

The square case No. 1 contains the earliest steps in the work of Mr. Edison, as well as that of Swan, Lane, Fox, Maxim, Sawyer, Latimer, Changy, Crookes, Rogers, Gatehouse, British Electric, Nothomb, Siemens & Halske, Siemens Brothers, Mueller, Gerard, Greinert & Fredrich, Swinburne, Cruto, Bernstein, Akester, Kurtzgen, Boehm and others. These particular lamps have been isolated in this case as they constitute the foundation of the Art as represented by the entire collection shown in the room. They have been set apart just as one observes is the case in visiting the Louvre in Paris or the Uffizzi Gallery in Florence, where there is a special room containing a few pictures of the greatest masters—pictures of which we have heard all our lives. In this manner we are duly impressed by these famous works of Art, whereas if they were scattered throughout the entire Gallery we would not receive the same impression.

I would call your attention to a lamp in Case 1, invented by an English butcher by the name of Rogers. In 1881-1882, in association with Mr. Edward H. Johnson, I had the pleasure of establishing the first central station for incandescent electric light-

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ing in the world at 57 Holborn Viaduct, London, England (started up January 12, 1882). Rogers hired a place a few doors away from the station and fitted up an exhibition of his system of incandescent electric lighting. In the basement he hung a number of large copper spheres about 18 inches in diameter, inside of which were placed smaller spheres. From these spheres, which were connected to the dynamo machine, fine wires were run to the individual lamps in various parts of the room. He explained to me with great earnestness that he had made one of the most wonderful electrical discoveries ever made, namely, that if electricity from the dynamo were permitted to spread itself over the surface of these copper spheres, it increased enormously in efficiency, and he was thus able to get from "two to three lamps per horse-power more" than Mr. Edison did. He not only believed this, but made certain investors believe it, although the system naturally did not last very long.

Edison's various platinum wire and foil lamps and his oxide of zirconium lamp, may be seen in this case and also his earliest steps in the paper and vegetable fiber filaments, and bamboo and graphite filament lamps, including the first lamp ever made in the pear shape, which form is now practically universal.

For many years Mr. Edison used bamboo for his filaments. There are said to be some three thousand varieties of bamboo, of which about 400 are of some particular use, the rest being largely weeds. He found in a certain hilly district of Japan a variety of bamboo called "Madake" bamboo, and discovered that when the outer calcareous surface and the inner pithy fibers were removed, he obtained in the center one of the most perfect cellular structures known, which produced a carbon filament of great strength and high resistance. I have explained to you that early inventors did not succeed in making a commercial carbon filament lamp, which was because the early lamps utilized either plates or rods of carbon of exceedingly low resistance, ranging from somewhat less than 1 ohm up to 4 or 5 ohms. Edison's carbon filament lamp had a resistance of 140 ohms hot and more than twice that cold. Possessing such a high resistance filament, he was enabled to connect his lamps across the electrical conductors like rungs in a ladder, and the higher the resistance of

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the filament, the more lamps he could place in parallel or multiple before the external resistance approached the low internal resistance of the armature, and naturally the greater the saving of copper in the distributing system.

Among the early carbon lamps shown in Case No. 1 are many of low resistance and frequently a number of these were connected in series and the sets of series lamps being then connected in parallel or multiple. Mr. Edison aimed from the very first to make each of his lamps an independent, self-contained unit, con-

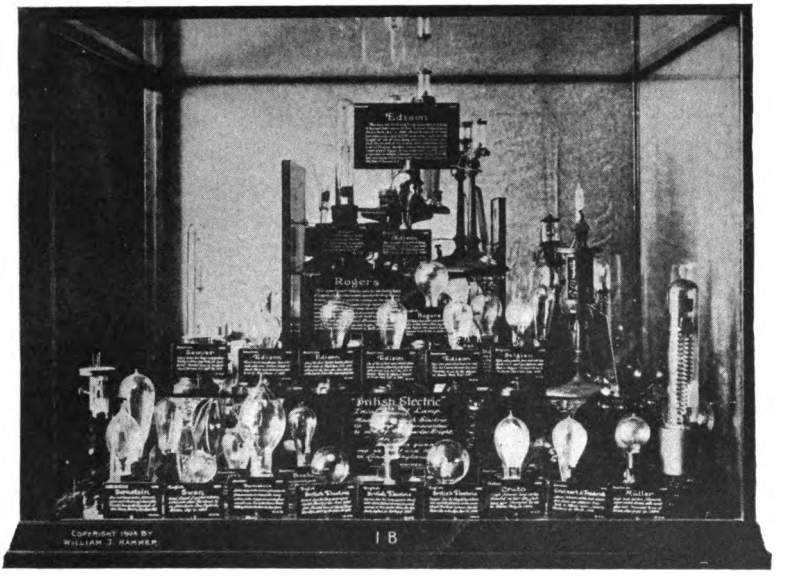

Fig. 2.—Case 1, Showing Original Types of Incandescent Lamps.

sisting of a high resistance filament of carbon hermetically sealed in an all-glass receptacle with platinum leading-in wires. I wish to call your particular attention to what seems to me an extraordinary fact, namely, that in 1879 the Edison carbon filament lamp was perfected and from that time until the present day, a period of 34 years, it has stood without a single salient feature eliminated or added.

Case No. 2 is devoted entirely to the work of Mr. Edison on the carbon filament lamp, and supplements the fundamental steps

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in his work as shown in Case No. 1. I believe that there is not a single important step in the work of Mr. Edison missing in this record, which embraces about 350 lamps.

Cases Nos. 3 and 4 represent the Art under the workers contemporaneous with Mr. Edison all over the world, the lamps being grouped chronologically. Among them are a number of Diehl's induction lamps for use with alternating current. In these lamps a secondary coil is placed inside the lamp and connected to the filament, the primary coil being wound on the outside of the globe, or the globe inserted in such a coil. This interesting lamp, for which the early development of the alternating current system seemed to promise great things, has left but little impress upon the Art. Bernstein lamps are shown in this case, in which the filaments are made by braiding a cotton and silk cover over a mandrel or wire; this covering was then slipped off and carbonized, forming a hollow filament of great strength and radiating surface. In the Cruto lamp, carbon is deposited upon a hair-like platinum wire. The inventor claimed that he secured a hollow carbon filament by subsequently volatilizing or fusing the platinum and leaving a hollow carbon tube.

Stopper lamps of the Westinghouse, Packard, Greene and other types are also shown in this case. In these lamps the filament stem is ground into the neck of the globe like a stopper in a cologne bottle. Bitumen and other compounds and lead were used to assist in holding the vacuum. This lamp was used by the Westinghouse Company to light the World's Fair at Chicago in 1893 and was so constructed to get around the Edison patents. It was supposed that this stopper lamp was absolutely new at that time, but in Case No. 2, will be found several forms of stopper lamps which Mr. Edison made as far back as 1880.

In Case No. 4, in addition to the standard types of lamps, will be found special classes of regulating lamps, signal lamps, sign lamps, Christmas tree and novelty lamps, etc. I am indebted to the Federal Sign System (Electric) of Chicago, for a neat initial sign, here shown, in which each letter is made of an incandescent lamp containing a number of filaments in series.

In the center of the case is a most interesting lamp and socket, for it was used by the speaker in the first electric sign which was

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ever made and which he constructed in December, 1881 and hung up in the Crystal Palace in London, England. It flashed the name "Edison" by means of a huge lever spring switch. The speaker also had the honor of constructing the first two "motor driven flasher" signs, which are now so universal, the signs having been constructed in 1883 and placed by him on top of the Edison Pavilion at the International Health Exposition in Berlin, the name "Edison" being flashed letter by letter and as a whole. Other forms of sign lamps are shown in which the letters are enamelled or etched on the outside of the globe. Another form designed by the speaker consists of a phosphorescent flashing lamp, in which phosphorescent material containing a trace of radium is combined with a vehicle which I have used for various purposes since 1902. This material is coated on the under side of a lettered round glass disc forming a transparent sign which is held by clips above the lamp. The lamp itself is flashed frequently and the phosphorescent sign stimulated by the operation of a thermostat in the lamp base.

The next group of lamps in this case are the regulating lamps. Here may be seen the Ries regulating socket, which employs a choke coil or single-coil transformer or reactance coil, and the Wirt "Dimalite" lamp regulator, employing resistance wire embedded in artificial stone. Also, the Johnson "Anylite" employing a coil of resistance wire in sections, and other types of lamps in which two or more filaments are operated in series or parallel or separately by turning a key or the socket or by pulling a cord, such, for instance. as the "Duplex," Phelps, Hylo, Trilight, Dublglow, Economical, etc. Among these is shown a lamp designed by the speaker in 1880, in which two or more filaments could be placed in parallel or series, by turning a switch. I also designed a lamp in 1880 in which a number of filaments of 8, 10, 16, 20, 30, and 50 candle-power were placed in one globe, and by means of a commutator on the base of the lamp, could be regulated up and down without employing any external resistance by merely switching the current from one filament to the other. Various forms of silvered reflecting and signal lamps are shown and you will observe one which is very badly worn which I made as far back as 1880 at Menlo Park.

About 12 years ago a number of companies were making what

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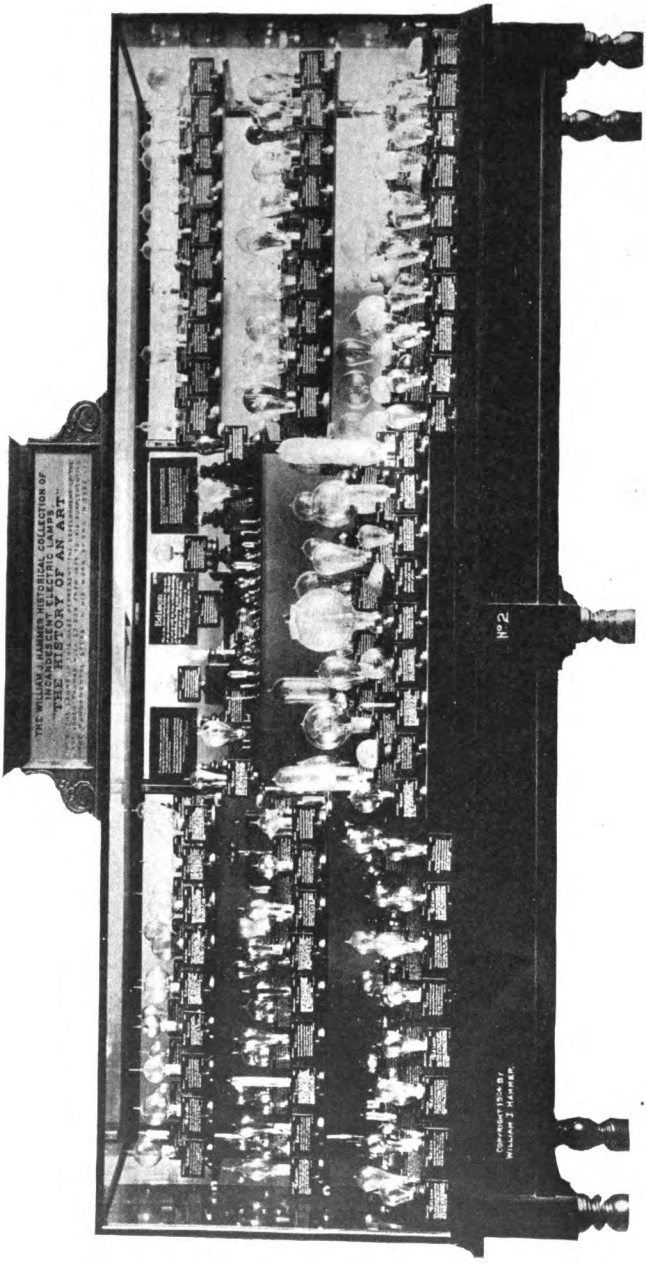

Fig. 3.—Case 2, Showing Stages of Development of the Edison Incandescent Lamp.

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were called "tipless" or "downward" lamps. Various types of these are shown in the collection. At that time it was thought that getting rid of the tip on the globe was new, but you will observe in Case No. 1 that many of the early workers, such as Lane-Fox, British Electric Company, Rogers, Mueller and others made lamps which were exhausted and sealed off at the bottom or side and were therefore tipless. The first colored incandescent lamp ever made is shown in Case No. 4 and the first ground glass, opal lamp and the first etched lamp in Case No. 1.

An interesting regulating lamp is that of Thompson, of Philadelphia. In this lamp a solenoid is placed on the inside of the lamp itself and this solenoid, in one case, operates a pair of springs and in the other case, a number of carbon rollers, which place more or less of the carbon filament in circuit as the potential varies. This lamp is absolutely impracticable, but it is an interesting illustration of the efforts made to lessen breakage and blackening of the globes due to bad regulation.

Case No. 5 illustrates the most recent developments in the Art, as it passed beyond the carbon filament and reached the stage of the perfected metallic oxide and metal filament lamps. The Nernst lamp is shown in its various developments both here and abroad from the early stages up to the present time. Also the tantalum, osmium, dicarbide of silicon, titanium carbide, helion, and many types of American and foreign tungsten lamps.

The tungsten lamp represents the survival of the fittest and, although its efficiency is so great that one might say that there is little excuse for the existence of the other types of lamps today, who will say that we shall not later find out something about carbon, of which to-day we have no knowledge. The late Professor Rowland once remarked that the Steinway grand piano was a comparatively simple piece of mechanism compared to the iron atom, and the same thing might be said regarding carbon, the constitution of which we know comparatively little of to-day. In the early days of the development of the Edison lamp, the gas people feared that gas was about to be wiped out of existence, and some of you may recall the great panic in gas stocks which followed the advent of the Edison incandescent lamp at Menlo Park. The Welsbach mantle came along later, and while it was practi-

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cally a failure at first, it was enormously increased in efficiency and improved in color by the addition of a small percentage of oxide of cerium to the oxide of thorium, of which the Welsbach mantle is largely constituted. This saved the gas situation and we may see the same thing occur in the case of the carbon filament lamp and perhaps other lamps.

One of the things which is certain to be perfected in the future, and I believe in the near future, in "cold light." In Case No. 5 I have arranged a section devoted to this subject, largely utilizing lamps and tubes borrowed from my little laboratory, which point toward "cold light". Among these is a lamp consisting of a tube with a stop cock in the center and a glass bulb at each end. In 1902 while visiting the late Prof. Curie, who, with Madam Curie, discovered radium, he drew a sketch on the blackboard of this lamp and suggested that I make one of them. If the gaseous emanation from radium is placed in one bulb and this bulb is then immersed in liquid air, the emanation is condensed; when the stop cock is then opened, it passes over into the bulb at the other end of the tube and stimulates the phosphorescent sulphide of zinc contained therein, which is thereby caused to give such a brilliant light as to enable fine print to be read some distance away.

A cathode ray lamp is also shown in which the negatively charged corpuscles of hydrogen gas are caused to bombard a disc coated with phosphorescent or fluorescent material, moving at a speed of approximately 70,000 miles a second, by means of which one may read a book at a considerable distance away.

Forms of Moore tubes are shown and also an interesting Moore gas lamp which operates at an efficiency of about one-fourth watt per candle. Unfortunately this efficiency soon falls to five or six watts per candle and the lamp does not last over 200 hours. Two tubes containing Neon gas are also shown. Who will say that we shall not find some efficient way to vibrate, oscillate or in some way energize a gas so that it will make an efficient transformer for electrical energy and produce an efficient cold light? I have now in my laboratory a tube filled with a gas which, on stimulation by a flash of current supplied by an induc-

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tion coil, becomes quite brilliantly phosphorescent, the light persisting after the current is shut off for half an hour or thereabouts.

Forms of Edison tungstate of calcium lamps are shown which give considerable light when connected to an induction coil. A vacuum tube lamp made by Mr. W. S. Andrews, of Schenectady, is shown, in which a sheet of metal is coated with tungstate of calcium and phosphorescent sulphide of zinc. This also gives a considerable amount of light when connected to an induction coil.

I have made many mixtures, of radium with sulphide of zinc sulphide of calcium, willamite, etc., utilizing these in the forms of powdered mixtures and combined with vehicles of various kinds. I was the first to make these in 1902, and they have been extensively used since for watch and clock dials, etc. I also made a lamp in 1903, which was exhibited in the St. Louis Exhibition in 1904 and is shown in the case, which glows constantly in the dark. I have since made much better ones.

The energy efficiency of the original carbon filament incandescent lamp was about 0.43 of 1 per cent.; that of the tungsten lamp is somewhat over 1 per cent. (about three times that of carbon) and there is probably no incandescent lamp that has an energy efficiency as high as 2 per cent. On the other hand, the light of the fire fly and the "pyrophorus noctilucus" have an efficiency of 96.5 per cent., as shown by measurements made by Professors Langley and Very with the bolometer and by Coblentz with the thermopile. We shall without doubt ultimately learn how these various creatures expend their energy and produce vibrations that come within less than one octave of the total spectrum of vibrations and which affect us as light. In all of our illuminants to-day, most of the energy is dissipated in long heat waves, so that what we must strive to reach is the goal of "cold light."

Now, just one word before I close regarding the formation of this collection. I was one of Mr. Edison's early laboratory assistants at Menlo Park, N. J., entering his employ in December, 1879. For a considerable period I had charge of the tests and records on the Edison lamp and subsequently became the electrician of the first Edison lamp factory. In the early days platinum was worth $7.00 an ounce; to-day it is worth about $45.00 an ounce.

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It was customary to throw the old lamps into a barrel to be smashed in order to recover the platinum, and in endeavoring to rescue lamps representing fundamental steps in the Art, I met with difficulty, being frequently told that the lamp I wanted had half a dollar's worth or perhaps two dollars' worth of platinum in it. But I would appeal to Mr. Edison or his very able associates Mr. Charles Batchelor or Mr. Francis R. Upton, and was finally allowed to form the nucleus of this collection, over which I have, metaphorically speaking, "sweat blood" for 34 years. About eight years of this time I have spent in various visits to Europe, and I have not hesitated to camp on the trail of any man who had a lamp that I wanted. As a result, I believe the collection does not lack an important link.

Some 24 years ago I tried to interest a number of gentlemen. Among them Mr. Henry Villard and Mr. Edison, in the establishment of an engineering and technical museum in New York City, in which engineers and inventors could place their models and records and have then safe-guarded, but I found, however, that there was too much inertia in this matter and I made up my mind that I would endeavor to carry to fruition the work of completing this collection, hoping that it would encourage others to make similar collections forming priceless records of the inception, development and perfection of other Arts and perhaps ultimately result in the establishment of a great engineering and technical museum where collections of this nature could be exhibited where they would not only be of great interest to the general public, but of great educational value to the student as well as stimulating and instructive to the engineer, the inventor, the manufacturer, the patent attorney and the historian. If my work assists in any way in securing this desirable end, I shall feel well repaid for my efforts.

I thank you for your courteous attention and I hope that some time in the future I may be able to supplement this informal address in a lecture upon the Incandescent Electric Lamp which will be to some extent at least commensurate with the importance of the Art and the time and attention I have devoted to it and to its history.

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NAMES OF LAMPS IN COLLECTION.

Edison	Greinert & Friederich	New Universal
Swan		"Watt"
Edison-Swan	Sawyer	Hardy
Ediswan	Sawyer-Man	Twilight
Swan-United	Nothomb	Fostoria
Brush-Swan	Hochhausen	Malden
Lane-Fox	Hammer	Esco
Maxim	Sun	Meriden
Weston	Franklin	T. A. Edison, Jr.
de Changy	Schmauser	Guage
Sawyer	Greiner	Premier
de Lodyguine	Schafer	Miller
Molybdenum	Jenny	Buckeye
Cruto	White	Femco
Gatehouse	Excelsior	S. A. C.
Kurtzgen	Belgian	Sunbeam
Swinburne	Ganz & Co.	Packard
Crookes	United Electric	Perkins
Bernstein	Van Choate	Boston
Müller	Guest	Westinghouse
Boehm	Phoenix	Novak
Gerard	Gilmore	Columbia
Latimer	Sun-Star	Seel
Rogers	Solar	Pray
Opperman	Monarch	A. B. C.
Diehl	Colonial	De Khotinsky
Thompson	Economy	Zugh
Stanley-Thompson	Brilliant	Peerless
Thomson-Houston	Tipless	Orient
Remington	Sterling	Banner
British Electric	Comet	Downward
Akester	Capital	Hylo
Alexander	Goebel	Economical
Richter	Von Kamerer	Robertson
Schuyler	Dubleglo	Moore
Duplex Co.	Elblight	Osmium
Siemens & Halske	Zenith	Aueros
Siemens Bros.	American	Osmi
Vitrite & Luminoid	A. E. G.	Osram

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Munder
Bryan-Marsh
Empire
Fabius-Henrion
Compagnie Centrale d'Electricite
Compagnie Generale des Lampes
Larnaude
Zurcher
Gelnhausen
Pintsch
Bayerische
Goosens-Pope
Phillips
Krementsky
Schonlah & Scharfs
Clerici
Vereingte E. A. G.
Sturm
Heany
Tungsten
Talmont
Adams-Bagnall
Hammer "Radium"
Pollard
Imperial
Thowless
Shelby
Kyle
Zalinsky
Kentucky
Star
O'Brien
Sunshine
Germania
Elbe
Novelty
Nernst

Osmin
Langhans
Crawford-Voelker
Tantalum
New Edison
Graphitic
Kuzel
Just & Hanaman
Hollefreund
"Z"
Zirconium
Canello
Hall
Fuller
Hygrade
New Universal
Aetna
Backstrom
Jaeger
Manhattan
Low-Watt
Am. M. & D. L. Co.
Schuckert
Elk
Polaire
Brown
Zuger
Challiet
X-Ray
International
Helion
Zernig
Envoy
Bergmann
Wolfram
Just
Justram
La Carriere
F. & F.
N. E. L. A.

Sunbeam
Sönnen
Phillips
Sirius
General Electric
S. & H.
Monowatt
Straight Filament
Mazda
R. E. C.
Pope
Guest
Laco
Hopfelt (Mercury)
Concave
Gabriel & Argnault
Durand
Andrae
Linolite
Trilight
Baetz
Eureka
Superior
Erner-Hopkins
Waverly
Cooper-Hewitt (Etched line lamp)
Flexilux
Novi
Berrenberg
Economique
Fabren
Andrews
Puluj (Phosphorescent)
Hammer (Phosphorescent)
Ebert (Phosphorescent)

W. J. H.—June, 1913

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THE POLLAK-VIRAG RAPID TELEGRAPH.*

By Antoine Pollak.

The rapid telegraph system I shall describe this evening is the result of 10 years of labor in producing a reliable rapid telegraph, in which task I had for some years the excellent collaboration of the late Mr. J. Virag.

Telegraphy means the production of mechanical movement at the end of a wire by electrical currents and the recording of this movement. If it is desired to produce *rapid* movements with the weak currents used in telegraphy, there are required a receiver almost without inertia and means for properly recording its movements, which should be very small owing to the limited power of the weak currents used in telegraphy.

In the Pollak-Virag rapid telegraph, a telephonic diaphragm is used as a receiver in connection with a mirror, a ray of light showing the almost imperceptible displacements of the diaphragm. These displacements measure only 1/1,000th of an inch.

The small mirror connected with the telephonic diaphragm reflects the light from an electric lamp, and projects a spot of light on a band of photographic paper. If the mirror is in vibration, the spot of light will move also and photographic paper records its movement.

The first Pollak-Virag apparatus had a receiver comprising a single telephone, and the message was received, in Morse signs, as a photographic record of wave-like form, similar to the records of submarine cables. This apparatus was able to receive 80,000 words per hour, but it was necessary to translate these Morse signs into ordinary writing.

It was then decided to improve the apparatus and make it record directly a legible script. We realized that the wave signs really included the principal elements of script writing, that is

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the upward and downward motion of the pen in writing. For instance, the above mentioned combination of a telephonic diaphragm with a mirror, etc., if properly applied with currents, would give the up and down motion of a writing pen, corresponding to the height of a letter, and a second telephone would control the lateral movement of the pen, corresponding to the width of the letters. If the two telephones act simultaneously and are supplied with properly chosen electric currents, then ordinary writing can be produced.

The two telephones, t_2 and t_1, representing one the vertical, and the other the horizontal componant of the script, are indicated in Fig. 1. The vibration of the centers of the diaphragms of the two telephones is transmitted by two small links to the mirror which is shown to the right. In order to impart a regular ad-

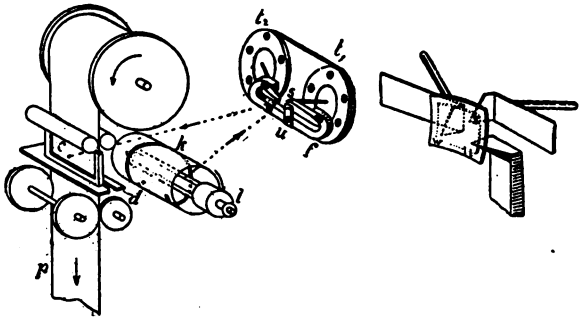

Fig. 1.—Receiving apparatus.

vancing motion like that of the writing pen to the spot of light which produces the script, the straight filament of an incandescent lamp, *el,* is hooded with the exception of a small slit through which the light comes to the mirror, and an advancing motion is given to this slit. This advancing motion is obtained by cutting the slit in worm-like form in the rotary drum, *k,* which confines the lamp, as shown in Fig. 1.

The necessary currents to produce the above mentioned vertical and horizontal components of the writing in the telephone t_1 and t_2 are obtained by means of a properly perforated strip of paper, which is fed into the transmitting apparatus, (Fig. 3) is shown to the left of Fig. 2; to brushes, one B_2, for the horizontal, and

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one B_1, for the vertical components of the script, make and break the current of two storage batteries, as the perforated strip of paper passes underneath them, the strip being pulled along by a motor-driven metallic drum, R. One of the storage batteries sends the currents to the telephone t_1, and the other to the telephone t_2.

Stronger current impulses are necessary to produce letters of a greater height, such as the letters *l, h, k,* etc., and less strong impulses to produce the medium height of such letters as *a, i, e,* etc. The perforated strip governs these impulses through using a greater or less part of the voltage of the storage battery, as

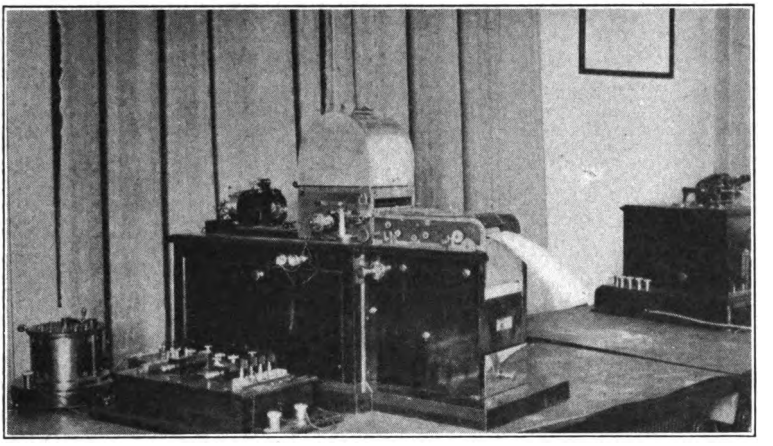

Fig. 2.—Receiver.

indicated in Fig. 3, the drum, R, being formed of several insulated discs connected with the battery.

The disc *a,* for instance is connected to the battery so as to have, say, a potential of 50 volts, and gives long vertical lines which represent the height of the letters *k, l, h,* etc. Disc *e* corresponds to 30 volts and gives short vertical lines, of medium height for such letters as *a, e, c,* etc. Disc *c* corresponds to 30 volts, and gives short vertical lines, but in the reversed direction; thus being able to produce the lower part of the letters *g, j, p, g,* etc. The horizontal impulses are controlled in a similar way, by the discs *d, e, f.*

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The right part of Fig. 3 shows roughly the electrical operation of the Pollak-Virag rapid telegraph; l and l_1 are the two telephone wires forming a loop which includes the vertical telephone t_1.

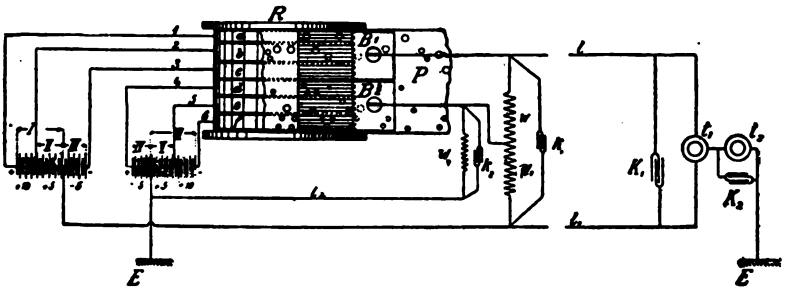

Fig. 3.—Transmitter and diagram of Pollak-Virag telegraph system.

The second circuit is used to feed the second telephone t_2, which produces the horizontal components(or the width) of the letters, and is made by joining the two wires, z and z, in parallel, the earth being used for the return currents. To obtain this parallel

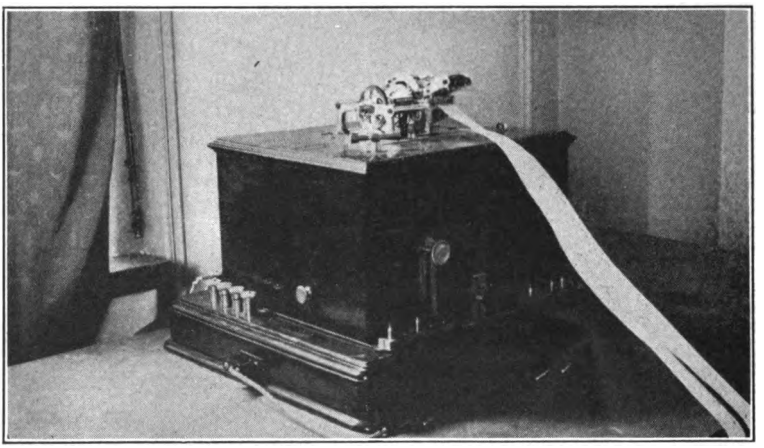

Fig. 4.—Transmitter.

circuit, the current for the horizontal telephone is introduced in the middle of the induction coil, w, w_1 which at the same time overcomes the disturbing effect of the self induction and capacity

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of the line, and divides the current into two equal parts travelling along the two telephonic lines l_1 and l_2. In the receiving station, these two currents flow together in the middle of the coils of the telephone t_1. The action of the two equal parts is opposite in this telephone, and thus no effect is perceptible on the diaphragm of t_1; but the current as it flows to the earth through the coils of the telephone, t_2 will produce movements in this second telephone.

Condensers are joined in parallel to the telephones which softens the action of the currents. Without the condensers the current would act as a hammer and produce violent vibrations which would impair the legibility of the writing.

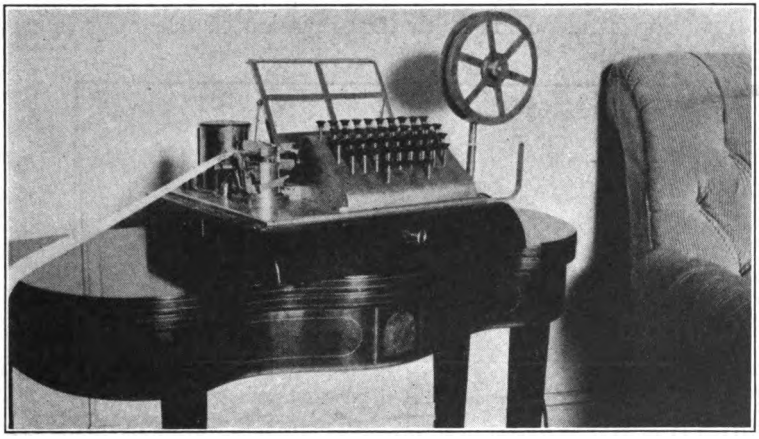

Fig. 5.—Perforator.

The perforating instrument (Fig. 5) for making the holes governing the impulses sent to the receiving station, is quite independent of the telegraphic apparatus. It is a kind of typewriting machine which, instead of printing a letter, punches a combination of holes in a strip of paper, as the operator works the keys. A given combination of holes represents the currents which reproduce a given letter in the receiving apparatus. When the strip of paper or tape, is unrolled on the motor driven drum, *R*, of the receiver (Fig. 3), proper impulses are transmitted through the wires in the receiver.

The Pollak-Virag system has given proof of its capacity in

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many official trials, such for instance, as those made by the French Government's engineers. These experiments have been so conclusive that the French Government by a presidential decree permitted the use of Pollak-Virag apparatus on all French telephonic lines.

The advantages of the Pollak-Virag system arise from the rapidity of its working. With a single loop of telephone wires it can do the same work as a Morse with twenty wires, as it easily transmits 40,000 words per hour. This means a saving of wires, as the traffic can be increased without building new lines. On the other hand, a pair of operators on a Pollak-Virag rapid telegraph can do the work of twenty pairs of operators working on Morse apparatus so far as the transmission of telegrams is con-

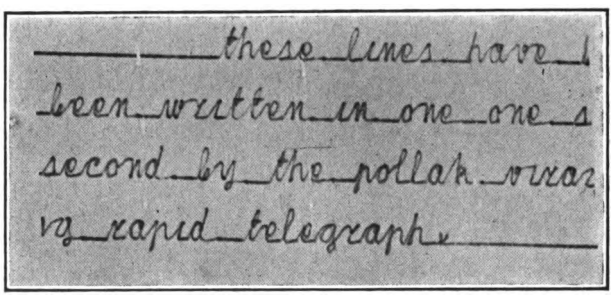

Fig. 6.—Message received directly from apparatus.

cerned. The perforation of the strip of paper which operates the transmitter is a rapid, easy and cheap, as a typewriter will easily perforate more than twice as many of words per hour as can be transmitted by a Morse or Hughes operator. By these means a great saving of human labor and a corresponding decrease in expense is realized. Besides, the Pollak-Virag system so simple of operation that an ordinary person can master it in a relatively short time.

In operation the system is not only rapid but dependable. No synchronism is needed between the motor of the receiving and the motor of the transmitting apparatus. The letters may be more or less spread when the transmitter runs slower or faster, but they will always represent a correct script. On the other

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hand, if some momentary induction disturbance occurs on the line, it may slightly deform a letter, but even this letter will remain quite legible. A sample of the writing is showed in Fig. 6.

The Pollak-Virag apparatus illustrated in Figs. 2, 4 and 5, was shown to the members of the New York Electrical Society in practical operation by the inventor, Mr. Pollak. Mr. Pollak transmitted a message on a perforated slip which contained 310 words in less than half a minute the message being recorded by the receiving apparatus. Next there was put on the transmitting apparatus an endless message, represented by a loop of perforated paper, so as to transmit continuous messages, the photographic paper being removed. To the operator who looks in a control window of the apparatus, the writing of the spot of light appears as a flame writing. The observation of this flame writing enables the operator to judge of the correctness of the script.

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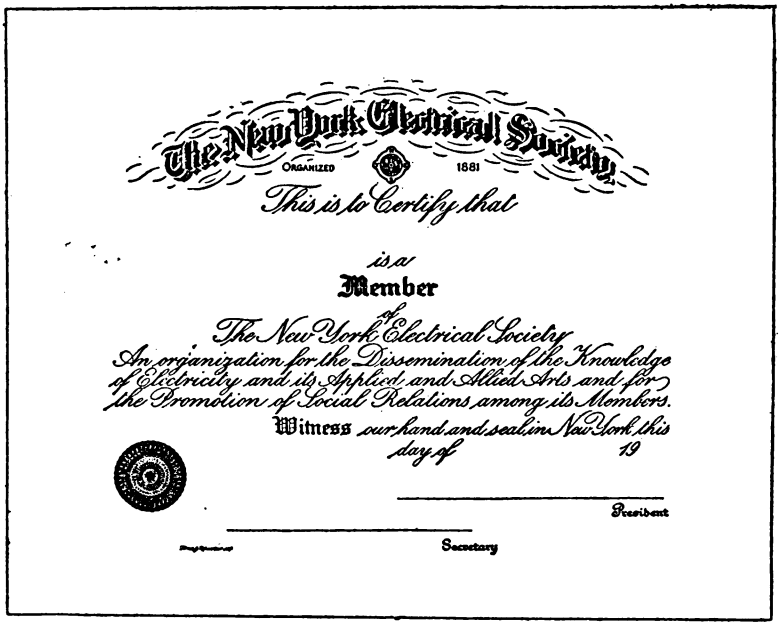
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BY

C. F. Lacombe

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TRANSACTIONS

OF THE

New York Electrical Society

NEW SERIES 1913 NO. 5

THE STREET LIGHTING OF THE CITY OF NEW YORK: ITS DEVELOPMENT AND PRESENT CONDITION.*

By C. F. Lacombe.

The street lighting of the city of New York, to the average citizen, is one of those simple obvious matters of daily life that is always with him and is taken as a natural phenomenon like daylight. It is only when it is very inferior and he can't see sufficiently well, that he notices, and then, of course, to complain.

As a matter of fact, however, since the birth of electricity, street lighting has grown into a fine art as well as a technical science. This is said advisedly, for successful lighting is a combination of both. Without artistic treatment, it is not attractive, and without scientific study it is not economical. It has been said many times that street lighting developed first as a police function and that this function is its most important one. Mr. Roosevelt, when a police commissioner, is credited with the remark that "an arc light is equal to a policeman." That is probably so, but the lighting of the city has to-day progressed far beyond the police requirements of his day. Street lighting is undoubtedly a great aid to policing the city, but the lighting that has served for that purpose is no longer satisfactory. In older days, even in this city, the night life was comparatively short; people out after twelve or one generally gave an excuse for it. To-day, after the theatre comes the supper, the cabaret show,

* A paper presented at the 318th Meeting of the New York Electrical Society, held March 28, 1913, in the Engineering Societies Building, New York City.

The *Transactions* are indebted to the courtesy of the Illuminating Engineering Society for the engravings used in this issue.

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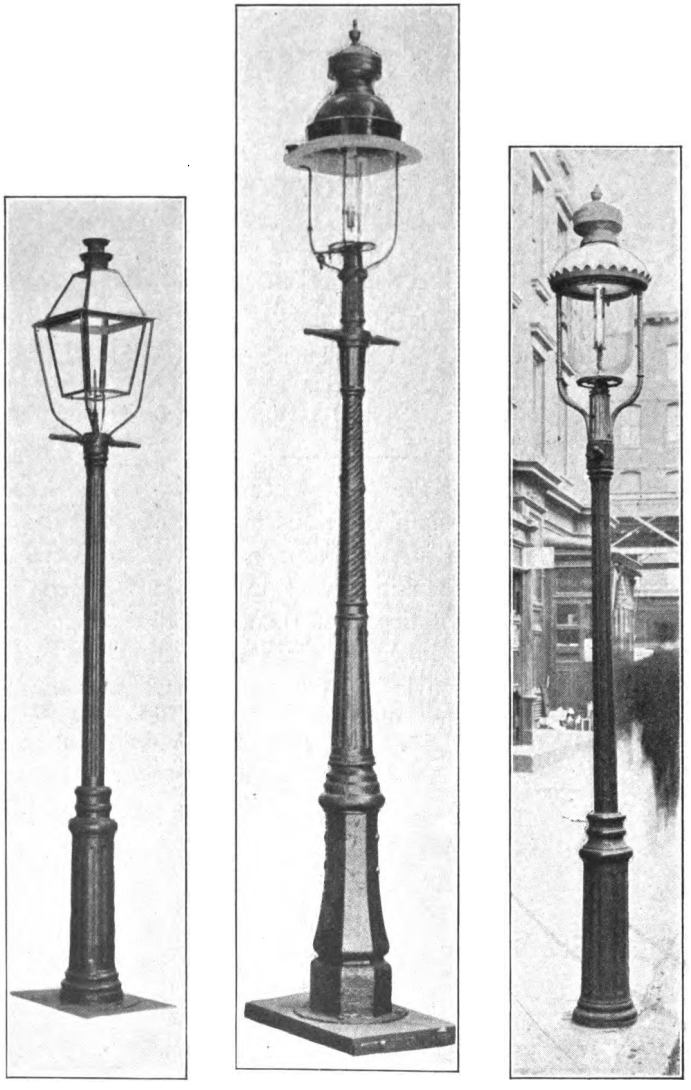

A B C

FIG. 1.—TYPICAL GAS LIGHT POSTS.

A. Old type, in use about 50 years, for open gas flame of about 13 candle-power. Weight of lantern, 14 pounds.—B. Early mantle type, 35 to 40 candle-power. Weight of lantern, 32 pounds.—C. Present mantle type, 35 to 40 candle-power. Center of illumination, 9 feet 6 inches from ground.

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dances until breakfast, etc. The night workers who produce all the things demanded by the present prodigals are thousands in number and the streets in Manhattan Island are now lighted not only for the police, but for the general use of the people who wish to be amused and the people who have to work to amuse them.

To contrast the old and new conditions, it may be noted that the amusement center of to-day was thirty years ago known as Longacre Square, rarely seen, lighted by open flame gas lamps and occupied by cheap little stores and grubby boarding houses.

It seems that the present congested conditions in Manhattan

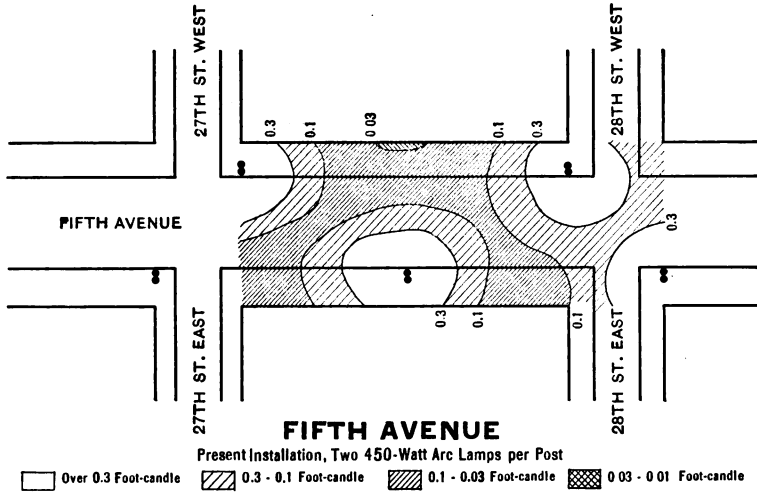

FIG. 2.—DIAGRAM OF LAMP LOCATIONS AND INTENSITY CURVES.

justify the statement that the day requiring only police lighting is past, that the day of real street illumination for great and general use through the night has arrived, and that any system of street lighting which does not fill this requirement is insufficient. Further, this has been due, without any question, to the impulse given by electric lighting and scientific and artistic advance of illumination by electricity.

In order to make the lighting situation in this city clear, it is necessary to describe briefly the limitations under which one has to work in the city government. Like all artistic or utilitarian things, illumination is a matter of money to a certain degree.

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Since 1905, the legislature has limited, properly, the prices to be paid for illuminating units, and the Board of Estimate and Apportionment, in the budget, has limited from year to year the number of units of illumination that may be added by setting the amounts of money that can be used in each borough. There are further limitations in connection with opening streets, etc., which restrict the time of construction, particularly in Manhattan and Brooklyn, so that only a certain amount of physical work can be done each year. In consequence, progress in improving lighting is slow and conservative in order to avoid frequent changes and should be so, particularly in the older sections of the city. None of you who know the illuminating art are willing

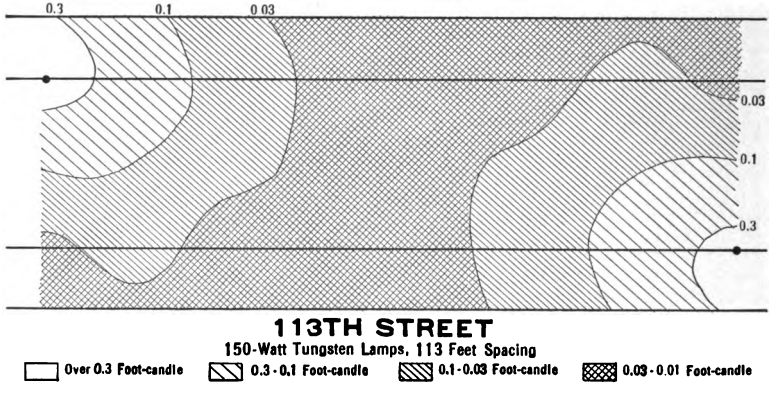

FIG. 3.—DIAGRAM OF LAMP LOCATIONS AND INTENSITY CURVES.

to say the last improvement has been made, or that the last unit of illumination has arrived. You also know how necessary it is not to jump at conclusions or adopt new units without careful study and trial, and in this term, units, is included both the light source, its reflectors and diffusing media. From this you can see that we are limited to the use of standard tried lighting units and that new ones cannot be adopted without a working trial, for the reason that the illuminating service purchased by the city must not be affected to its possible detriment.

The city contracts with public service corporations to supply it with certain illumination and illumination service on its streets. That means that the illumination is to be given by certain proved

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lighting appliances, or in other words, proved units, and that these appliances or units are to be kept in a condition giving as nearly as possible perfect operation. The term "perfect operation" is the definition of "good service." It depends on many elements and great attention to detail.

In 1888, when first engaged in electrical work, a small handbook was given me which said "The best electric system is the man who runs it"—a crude way of saying the best illuminating system depends on the efforts of the men who run it. This was

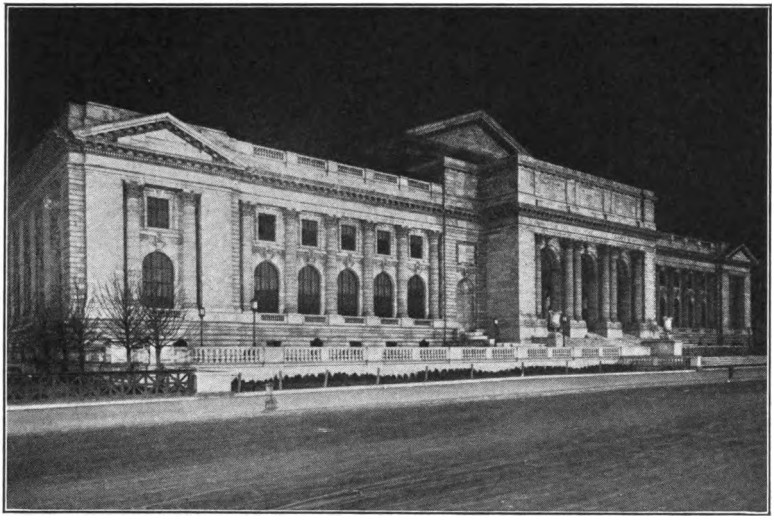

FIG. 4.—NIGHT PHOTOGRAPH OF NEW YORK PUBLIC LIBRARY.
Lighted from enclosed arc lamps on the opposite side of Fifth Avenue. Approximately 0.1 foot-candle on face of building.

in the days when there were many different so-called systems of producing electricity for illumination work. Now, the efforts of the men who operate a lighting system largely define whether the householder or the community get good or bad service, and the clumsy epigram quoted is just as true now as then.

Good service in electric, and largely in gas, lighting, depends on the active strength and reserve capacity of the central station and its relays, the perfection and reliability of the distribution system, the detailed care and attention given to the most reliable lighting appliances obtainable for the system, and last, but not

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least, the discipline, co-ordination and co-operation enforced between the above elements as established and maintained by the man in charge. This man and his loyal assistants may really be called the slaves of the lamp; and those of us who have been such slaves, know the strange fascination of this work and its demand for the sacrifice of all else to it. But that fascination and devotion mean good service, and you can never get successful lighting without it. Nor can you get that steady, continuous illumination, without which any attempt towards agreeable or artistic lighting is futile.

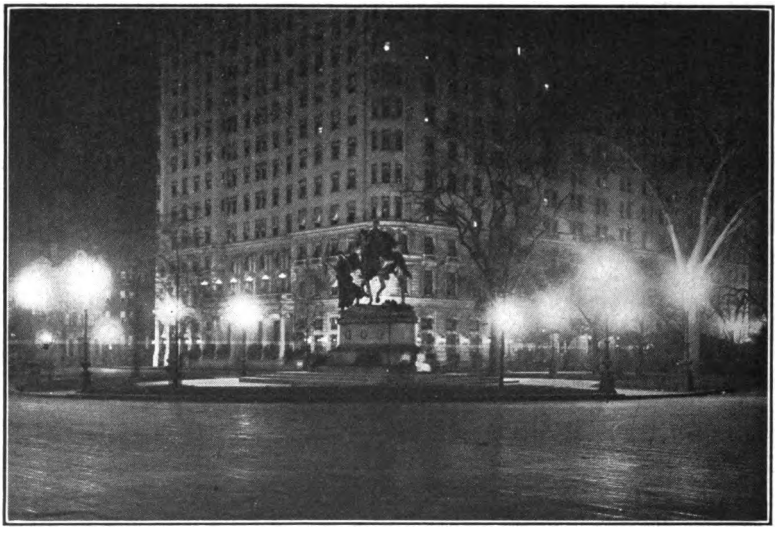

FIG. 5.—PLAZA AND SHERMAN MONUMENT.
Illuminated by flaming arcs, enclosed arcs and tungsten lamps; flaming arcs beyond range of camera.

Good service is rare, but rarer still is co-operation between the city and the contracting company. This, on the city's part, means strictly fair, semi-judicial engineering supervision, without any political bias. The city must jealously watch its own interests through experienced and unbiased engineers and insist on the observance of simple business rules, such as a steadily decreasing price for a steadily increasing use of standard units.

On the company's part, this co-operation requires a marked

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civic pride, an ambition to make its equipment and service the best possible within its means, and a broad policy of development encouraging increases of future *additional* business. Examples of both are rare indeed in this country, but a few shining examples do exist.

Assuming these conditions to be obtained, then, let us see what choice is given us as to the lighting appliances to be used. It is apparent on a moment's thought, that, as stated, appliances must be well tried and standard. New appliances cannot be used

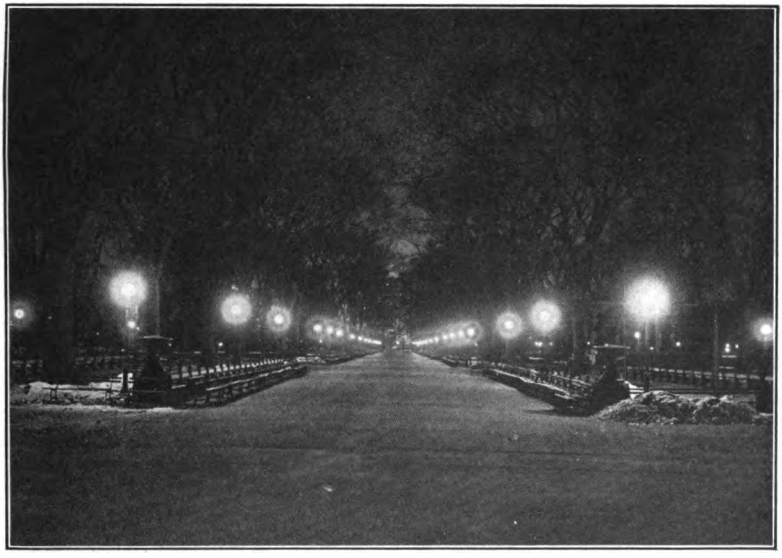

FIG. 6.—CENTRAL PARK MALL.
Ornamental ball tungsten posts, 60 candle-power.

on regular service. They must be given long service tests in by-ways and unimportant sections, often improved and re-tried until they become reliable and of real value. Of such available appliances to-day, we have the arc lamp of standard design for both types of current supply and for both multiple and series systems; the incandescent lamp, in various intensities of the carbon, graphitized and metal filament types, for similar current supply and distribution systems; the mantle gas lamp with either vertical or inverted mantles, increasing in number of mantles for

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increasing illumination; and naphtha vapor mantle lamps, giving the same illuminating effect as vertical mantle gas lamps. In addition, but not available in all parts of the city, are the high-candle arc lamps using a metallic electrode, with which much can be done. In Manhattan, where the greatest congestion exists, we are now trying long-burning white flaming arc lamps, giving still higher illumination for general street lighting, by installing a limited number of same on Broadway, above 47th Street, and on 7th Avenue, above 34th Street. This list of lamps, then, comprises our lighting units and they are the tools with which we must work at present.

This city differs from others in that we have two systems of street lighting, one low-tension, direct and alternating current multiple, in the borough of Manhattan and part of Brooklyn, whereas in all the other boroughs and in by far the larger part of Brooklyn, the street lighting is by means of comparatively high-tension, direct and alternating series systems, with a few minor exceptions. Gas supply for mantle lighting is available throughout the greater city, except in a few remote sections. Naphtha mantle lamps are still used for frontier lighting, where neither gas nor electricity is available. It was formerly used in parks, but is now being abandoned for obvious reasons, in favor of the tungsten incandescent lamps. Of these various units, in the greater city, there are:

19,180 arc lamps.
17,991 incandescent lamps.
78 flaming lamps, permanent and on trial.
44,653 single-mantle gas lamps.
28 inverted-mantle gas lamps on trial.
1,816 naphtha vapor lamps.

a total of 83,746 lamps of all types. Expressed empirically and approximately, in terms of horizontal illumination, these lamps give an illumination equivalent to fifteen million candles, and are furnished by 28 lighting companies. For the purpose of street illumination, these lamps are used in the following manner:

Arc lamps, reinforced by flaming arc lamps, at points of great congestion, as at Times Square, Manhattan.

Arc lamps on main avenues and business streets, practically over their whole length in Manhattan, and as far as necessary in

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A B

FIG. 7.—LAMP POSTS.

A. Ornamental type, 500-watt tungstens.—B. High type, flaming arc. Globe about 39 feet from ground.

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other boroughs, merging into tungsten incandescent electric or gas mantle lamps.

Gas lamps are generally used in the residence districts and on unimportant streets, little used at night, although of late, for many reasons, the tungsten lamp has made great inroads on this territory.

Ten years ago last month, when the engineering direction of the illumination of Manhattan and the Bronx was put in the charge of an engineer, it was found to be inadequate, unsym metrical and out of date; the arc lamps on the main avenues were insufficient and often spaced irregularly, too far apart and not in symmetry in line or in height, except where standard fixtures were employed; open-flame gas lamps were in the majority, with mantle gas and arc lamps often mixed in with them. In other words, there was little, if any, system of lighting.

As soon as possible, this was corrected. First, prices were materially reduced by continuous agitation, and second, a plan of lighting developed. All open-flame gas lamps were discontinued. Arc lamps were practically doubled in number at street and avenue intersections and symmetrically arranged where possible on street house lines, so that the illumination was made as uniform as it could be with the funds allowed. Mantle gas lamps were put on existing lamp-posts on all residence streets where arc lighting did not exist, as was the case in a few quarters. This system as a whole has proved efficient and has been followed with improvements as they were worked out. The result you can see in the uniform increased system of distribution of light sources in long straight parallel lines, exemplified best, first by Seventh Avenue above Central Park, and Fifth Avenue from Washington Square to 60th Street, and now by almost all the avenues in Manhattan, from west to east, running north to south, as well as on the main streets running east and west.

Late in 1905, the engineering charge of the illumination of the greater city was put under one engineer as Chief Engineer, and early in 1906 such control was formally assumed. The same general system as used in Manhattan and the Bronx was put in effect in the other boroughs and the bureau organization in these boroughs made to conform to the simple system of development in illumination just described in Manhattan. It was modified

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in some ways, for in the outlying sections of Brooklyn and in Queens and Richmond the problem was quite different. In these boroughs it was the illumination of small towns and centers, with long connecting roads through truck farming districts. These

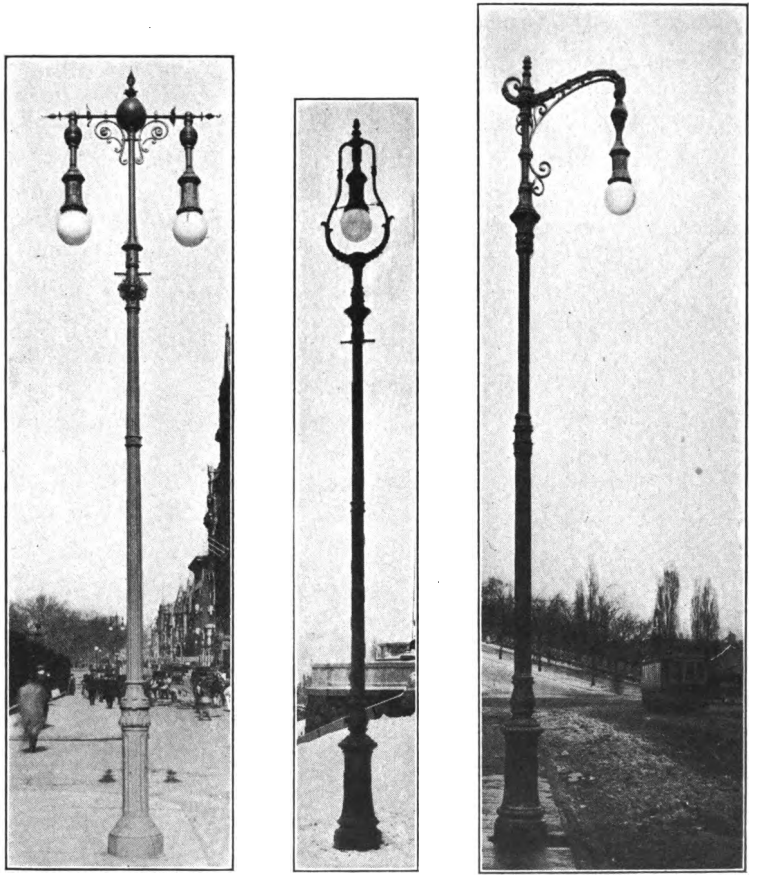

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FIG. 8.—ARC LAMP POSTS.

A. Twin lamp post used on Fifth Avenue.—B. Lyre top post, used in center-parked plots on broad streets.—C. Reverse scroll bracket post, used on lower Seventh Avenue and also with flame arc lamps.

districts are lighted by means of far flung alternating and direct current series systems of electrical distribution overhead on poles,

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with all the limitations of such suburban systems and companies. The same rule was worked out in symmetrical, continuous and uniform illumination with arc and tungsten lamps, and there are now established certain lines of well-lighted roads from the City Hall in Manhattan, north to Yonkers, east to Nassau County, and central Long Island, as well as along its north shore, southeast to Rockaway, south to Coney Island, and excepting the ferry, to the southernmost point of Staten Island. Cross and interconnecting roads through country districts are also carefully illuminated. Other projects on this system are now building or

A B

FIG. 9.—LAMP POSTS.

A. Ornamental arc type, also used with 500-watt tungsten, Sherman Square.—B. Original ornamental tungsten type.

planned, such as the Boston Road and Pelham Parkway and Park to Pelham and the south shore of Connecticut, another route via the Eastern Parkway, Brooklyn, to the Merrick Road and the south shore of Long Island.

This general development is now established on such basic lines that it can develop consistently and without duplication of

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equipment expense with the use of the present units of illumination, so that until congestion spreads from Manhattan, the lower portion of the Bronx and Brooklyn, to the outlying sections to the extent that a considerable change from overhead line construction to underground subways becomes necessary, the development need only be toward units of greater intensity and not a change in system or equipment to any considerable extent.

A certain handicap will exist for some years in obtaining the best distribution of illumination in the suburbs on account of the overhead lighting lines and lighting being kept on one side of

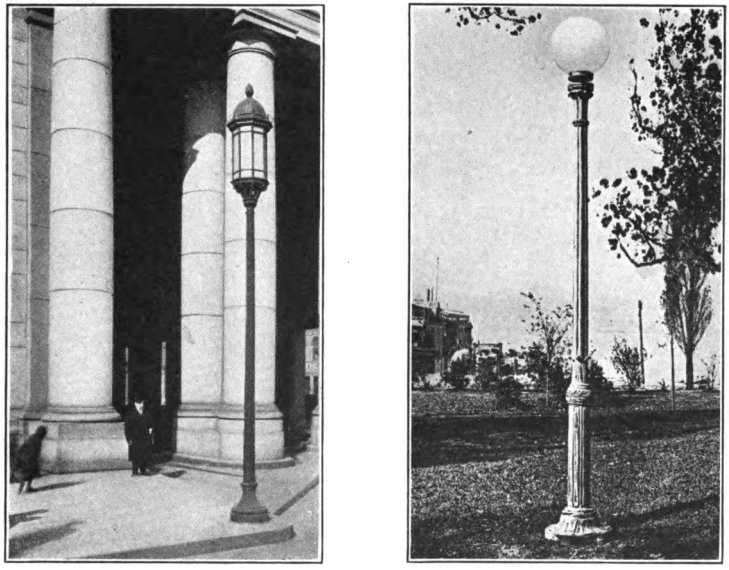

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FIG. 10.—TUNGSTEN POSTS.

A. Pennsylvania Station post.—B. Ornamental type for 150-watt tungsten; approved by Art Commission; convertible for use with 4-mantle gas lantern.

the street to avoid duplication of pole lines, but this, in time, will be removed.

In the congested area of Manhattan and in the Bronx, where underground distribution exists, the locations of the lamps on the main avenues are final; and to realize the full perfection of the present plan, only more powerful sources of illumination are

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needed, and it is to that end the experiments with flaming arc lamps on Broadway and Seventh Avenue are being made.

In the development of lighting in this city we have been careful to avoid freak or too accentuated lighting, on certain streets, as has been the case in some cities. The attempt has always been to keep to uniform, agreeable lighting, avoiding light sources of high intrinsic brilliancy and consequent glare; but where used they are carefully diffused or kept out of the range of vision.

It is all a slow, but so far, sure progress of evolution, development, and education. The results of the original plan of ten years ago now show in Manhattan, the Bronx and Richmond, and are beginning to show in the thoroughfares of Brooklyn and Queens. The mixture of lighting units has been generally removed or is in process of removal. In the last ten years, the illumination of the greater city, as specifically defined, has increased, under this system from seven million candles to fifteen million candles, or an increase of 118 per cent. at an increased cost of 19.2 per cent.

It is a peculiar and somewhat odd fact about all this development, that except in a few isolated instances, no one in this city seems to realize the improvement made in its lighting in later years. Few newspapers have ever mentioned it, and then but casually. No realization that a logical engineering scheme of development is taking place has been noticed, although it has been inherently correct enough to have been supported by the commissioners of four political aministrations of the city government. It is only fair to say that the technical journals and societies have discussed it somewhat, and a number of other cities have noticed and studied the lighting and fixture in use here with a view to their use in their own cities; in some cases our system having been adopted by them.

Even in this, a sort of peculiar pride is taken, for this city, rushing on in its career to the goal of the greatest city of the world, has little time to do much but growl at real or fancied obstructions to its progress. In consequence, to keep up to the extension of the lighting demanded, the lighting officials of the city department in charge of lighting have had little time to do anything but work, their efforts being devoted to making up for the lack of development in the past, and hurrying forward to

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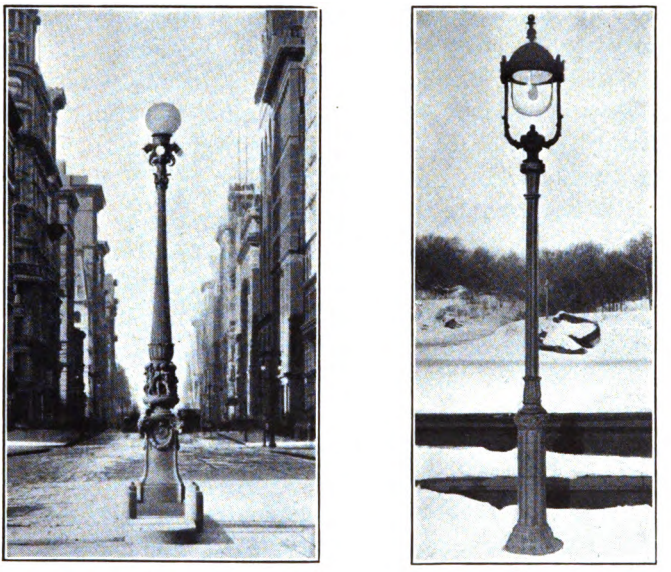
meet the present demands of a greatly congested world center. In a negative way, the work has been noticed; for example, since the avenues have been doubled and tripled in illumination, we have heard a complaint that the side streets in Manhattan and the Bronx are dark, and such complaints are always listened to attentively, because they help the engineering scheme by impressing the political and financial powers that be. The side streets are comparatively dark, but in 1904, when the mantle gas lamps re-



A B

FIG. 11.—SPECIAL TUNGSTEN POSTS.

A. Post in front of Astor Hotel; designed by Henrik Walliu and presented to the city by the Astor Estate.—B. Post used in park roadways; designed by Henry Bacon for the Municipal Art Commission.

placed the open flame gas lamps, these streets received more than three times the old illumination, so you can imagine what that illumination was.

The installation of the new lighting is awaiting the necessary funds. It may be truthfully said that were this city thrown back in a day to the lighting of ten years ago, the contrast would be so extreme that there would probably be great alarm on account

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of lack of illumination. In the elapsed time the increase has been slow, and, in consequence, not noticed perceptibly except from year to year.

The amount of lighting required to illuminate the streets satisfactorily is determined largely by the use of the streets, but speaking comparatively, it is a matter of education. The example of a street attractively and brilliantly lighted, like Fifth Avenue, with city lamps, or Broadway, which is lighted by advertising signs, shortly becomes the standard, and requests for increased lighting on other important streets usually refer to it as the type desired. A poorly lighted city having only poor lighting standards improves but little, the inhabitants being apparently satisfied. But once begin to improve the street illumination properly and the continuing demand for additional lighting begins. The storekeeper quickly learns the value of a well-lighted street and the citizens at once realize the comfort of it.

It is desired to impress you with the fact that under the engineering scheme all new lighting is carefully worked out mathematically and geometrically, on lines of proper illumination design. A temporary equipment is then erected, movable, if desired and the final effect obtained by the actual trial and observation on the street. All suitable kinds of reflecting and diffusing devices and glassware are tried until the best result we can obtain is reached. This example is then measured and plotted photometrically and checked, or corrected, as the case may be. Lighting is no longer installed empirically or by guess work. As examples, Figs. 2 and 3 show diagrams of lamp locations and intensity curves for an avenue and an ordinary street.

The newer lamp-posts used for the improved lighting are also designed with great care. Even before the Municipal Art Commission, took up this matter in a systematic and effective manner, as they did some years ago, the New York Edison Company had anticipated the demand for more attractive fixtures and have been, and still are, pre-eminent in this regard.

It is well to state here, as one of our working conditions, that with few exceptions the arc lighting posts and fixtures belong to the companies throughout the greater city, while the gas lamp-posts all belong to the city, as do the tungsten posts in the streets

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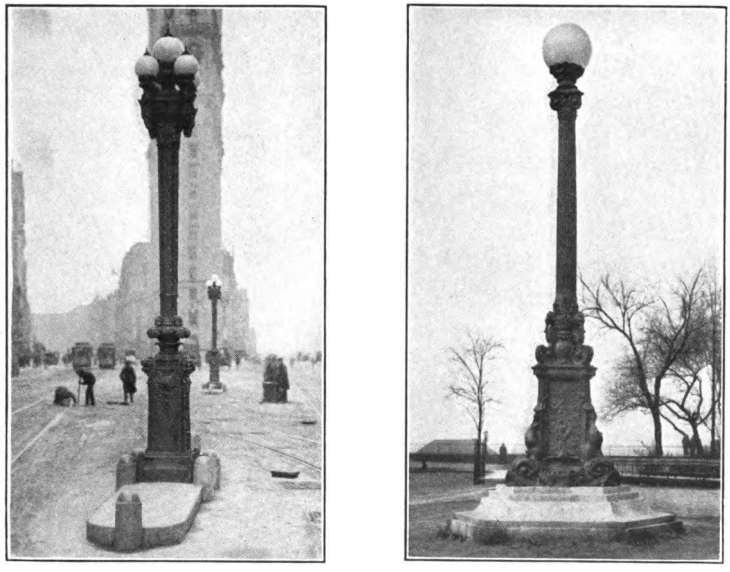
and parks on underground service. The lanterns and lamps themselves belong to the various companies. The posts now supplied by the lighting company were first drawn on paper, then life size plaster models made and revised, then the patterns developed and corrected until a satisfactory and harmonious result was attained. This combines artistic effect with engineering construction. These posts are then submitted to the Municipal Art Commission in every case and their criticisms embodied in the final result.



A B

FIG. 12.—SPECIAL ORNAMENTAL TUNGSTEN POSTS.

A. Post designed by Mr. Ciani and presented to the City by the Municipal Art Society.—B. Post designed by Allen G. Newman and presented to the City by the Daughters of the American Revolution.

The city's posts also go through this process. In one case the art commission had designs drawn and paid for, of both the lantern and posts for tungsten lamps for Central Park. This design has been used extensively throughout the city since and has been copied by other cities. The new posts for side street lighting will also be submitted to them when funds are received, and it is hoped that the old ugly gas lamp-post will shortly disappear from Manhattan.

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It is natural that the attempt to make the lighting and fixtures artistic should begin, like the improved lighting system, in the borough of greatest congestion, where it is needed most, and where the lighting is required to be not only useful but strong, uniform and agreeable.

Manhattan is fortunate, in the engineering sense, in being supplied with its lighting service by a low-tension multiple system, which is flexible and very adaptable to artistic effects with safety. This lighting current is distributed by underground lines, and with energy supplied from the greatest electric generating station, gives the best obtainable service. The problems of the engineer in the lighting of this great city are much diversified. He must proportion the lighting to the needs of the various streets or sections, and to their importance, due to greater or less use. He must lay out a system capable of great increase without expensive change of equipment, or the contracting companies will object; he must lay it out on economical and efficient lines and obtain judicially fair prices within limits, or the city administration will object. He must try to eliminate glaring lighting, or the illuminating engineers will protest and he must make it agreeable and as artistic as possible, or the Municipal Art Society and commission will criticise.

Agreeable and successful lighting is a combination of the efforts of all the different interests mentioned. It is not only a matter of artistic posts, but also artistic lighting, if that term may be used. To produce the best results, one must have the support of the city and the contracting company. The posts and the lighting must both be artistic and agreeable. The position, height and design of the supporting post have much to do with the effect of the distribution of the lighting, as well as its cost.

In the combination of these elements the municipal administration, the company, the artist, and the engineer, can well work together. The administration should provide the necessary funds for steady progress in lighting both in extension of service and improvement in illuminating units, etc.

Within limitations the artist must not demand too extremely artistic design in lighting. It is too costly except in certain in-

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stances. In the general lighting of a great city, the useful side must have as great weight as the artistic.

The engineer also should not cling too closely to the most efficient and economical devices which obtain only the greatest illumination at the lowest cost, for the lighting must be made

FIG. 13.—BRACKET FOR NARROW DOWNTOWN STREETS.

agreeable to the eye. In street lighting, unless surrounding buildings are to be specially illuminated, the useful rays are those that can be directed towards the ground. To make this agreeable, the point source of an arc lamp, for instance, must be made into a ball of softened light by diffusing globes or shades, and this, so far as is possible, thrown towards the ground by either interior or exterior reflectors. This sacrifices efficiency to a certain amount by the absorption of the light, and demands either closer

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spacing or more powerful sources of illumination at greater heights from the ground. It is, consequently, more expensive. So far, it has been used mainly in Manhattan and there, principally on its main avenues.

In other locations, we approach nearer to the naked source of the light. This, in turn, means glare and is not as agreeable, although very useful and less expensive. Considerable success in suburban sections of the city has also been attained by abandoning the intense arc unit and using three to four 60 or 70 candle-power tungsten lamps, thus obtaining better distribution, with less glare, and at about the same cost.

It is towards aiding the extension of diffused lighting in sufficient amount that the efforts of all should be devoted. The administration, the company, the citizen, the artist and the engineer should all work to this end. The progress of this lighting depends on the aid the other factors in this work give the engineers in charge.

There is nothing new in this plan of lighting. The ancient torch bearer always held his torch as high as possible to keep the glare out of one's eyes and to throw the rays over as great an area as possible. The engineer uses his new facilities for lighting in the same way, puts them as high as possible, and throws them over the greatest area he can. He only adds to the torch bearer's efforts, the diffusing globes and downward reflectors.

You have been shown the results of ten years' work, carefully planned in advance, and the great improvement made in the illumination of this city, with a relatively small increase in cost. Now just a final word as to the future.

In the borough of Manhattan, the locations of the posts for street lighting have been obtained and need only more powerful illuminating units in order to bring out the full effect of the proposed system. It is thought that this year more powerful and efficient sources of illumination have arrived, both in small and large units. The increased efficiency of the tungsten lamp, which is the smaller unit, gives us more illumination per unit for the same energy than formerly, so that in the suburban districts we can increase the illumination by changing lamp for lamp without any more expense for energy consumption. With the 150-watt

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unit for side streets in Manhattan, excellent results will be obtained on these streets. The larger unit, the flaming arc lamp of the long burning type, is now nearly perfected; its large illuminating power per watt makes it very desirable, and it is now being used and will be used to illuminate streets in the center of the city, in those areas which are congested at night.

The further development of both the tungsten and flaming arc lamp is now an assured fact, and it is with these two main units that we hope to work out the further illumination of the city. In addition to these, magnetite lamps can be used in districts where series arc lighting is in vogue. The flame arc lamp and the magnetite lamp are both types which would be used in important sections or streets. By far the greater territory in the city will be covered for a long time to come, however, with our old standby—the standard enclosed carbon arc lamp and the mantle gas lamp with either upright or inverted mantles. It is believed that with these illuminating units and the use of the same care in the future to follow the system of illumination described to you; that the lighting of the city can go forward as rapidly as desired, within the physical and financial limitations, and that in due time it will become not only an attractively lighted city but the best lighted city in the world.

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New York Electrical Society

THE purpose of the New York Electrical Society, founded in 1881, is to present in popular but none the less authoritative form, the latest advances in the electrical and allied sciences and arts, and to encourage professional and social relations among its members. All persons in good repute and interested in electricity and its applications, are eligible to membership.

Upon request, an application blank and list of members will be forwarded by the Secretary. When returned filled in with the name, address and occupation of the applicant, and with endorsement by two members of the Society, the application, upon approval by the Examining Committee, will be presented for action at one of the regular meetings of the Society.

The entrance fee is $1.00, and the annual dues, $3.00.

GEORGE H. GUY, Secretary,
Engineering Societies Building, 29 West 39th Street, New York.

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The Society Badge can be supplied in four different forms, as follows: Vest pin, $3; scarf pin, $3; watch chain, $3; lapel button, $4. All patterns

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NEW SERIES JUNE-OCTOBER, 1913 NO. 6

Transactions

of the

New York Electrical Society

Organized 1881

ISSUED MONTHLY EXCEPT DURING JULY TO OCTOBER

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R.D.W.

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BY

Lieut. T. G. Ellyson, U. S. N.

THE APPLICATION OF THE GYROSCOPE TO THE FLYING MACHINE

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DESCRIPTION OF THE ELEVATOR EQUIPMENT AND THE ELECTRIC INSTALLATION IN THE WOOLWORTH BUILDING, NEW YORK CITY

BY

Charles E. Knox

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An Organization for the Dissemination of the Knowledge of Electricity and its Applied and Allied Arts, and for the Promotion of Social Relations among its Members.

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TRANSACTIONS

OF THE

New York Electrical Society

NEW SERIES 1913 NO. 6

SAFE FLYING AND THE FLYING BOAT.*

By Lieut. T. G. Ellyson, U. S. N.

I fear that the title of this paper is in a certain sense misleading, for I do not intend even touching on safety devices, such as speed indicators, inclinometers, air compasses, automatic stabilizers, and the many other means being developed to make flying safer; nor do I intend entering into any technical discussion. I was first requested to deliver an address on the subject of the "Development of the Flying Boat," and as in my opinion the two subjects more or less merge into one, I will try to treat them together.

"Safe Flying" may be said to date from the time when over-water flying was made possible; that is, when the aeroplane fitted with floats was proved a practical machine for rising from, lighting on, and manoeuvering on the surface of the water, and also made capable of easy control in the air. There are many who claim to have been the first to conceive of the idea of placing floats or pontoon under aeroplanes; others claim to have been the first to have succeeded in rising from the water, and still others claim first honors for landing on the water. Be that as it may, it is an undisputed fact that Mr. Glenn H. Curtiss was the first person in the world to rise from and land, on both land and water, using the same machine. This was accomplished in 1911 and to him alone is due all the credit for the beginning of

* A paper presented at the 319th meeting of the New York Electrical Society, held April 17, 1913, in the Engineering Societies Building, New York.

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safe flying as it is considered in this paper, or hydroaviation as it has been called.

The development of the hydro-aeroplane, especially in this country, opened larger fields to the aeroplane industry and gave it a boost from the sportman's and pleasure-seeker's point of view, that otherwise it could never have received. I am not taking into consideration the professional nor the military flier, and aside from these, if we count those in all the world who have taken up aviation from a purely sportsman's point of view, the number will be found very small. I am not referring to those men who have made occasional trips in the air, nor even to those

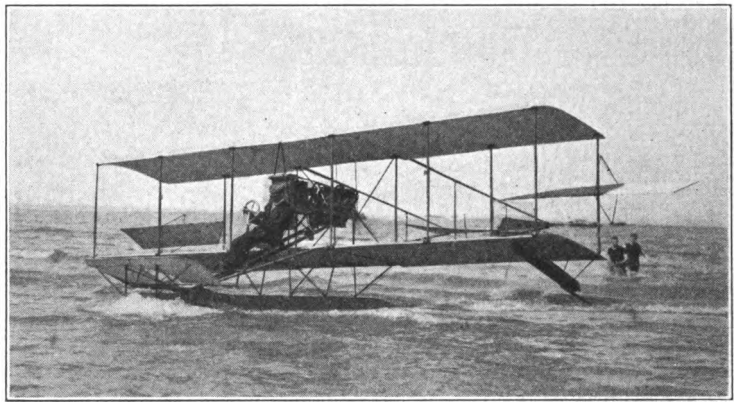

FIG. 1.—CURTISS HYDRO-AEROPLANE.

who have owned aeroplanes and employed others to drive them but to such men as Drexel and Harmon. It will be found that the scarcity of this number is amazing, and moreover that the few who did fly for pleasure only, soon gave it up.

The hydro-aeroplane does away with the necessity of large land aerodromes, which are comparatively scarce, for any body of water is a natural and an ideal aerodrome. Again, the air currents over water, especially large bodies of water, are always very much steadier than over land, and there is always a smooth, level place to come down, when this becomes necessary owing to motor trouble or other mishap. For this last reason the danger of flying is reduced to a minimum, and that is why hydro-aviation

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is termed "Safe Flying." Heretofore if one became interested in aviation to the extent of desiring to learn to fly, it was necessary to go to some aerodrome, generally inconveniently situated, and begin by running over the ground in an aeroplane alone, or be instructed in a passenger machine, with a chance of being injured in either case. Over water the worst that can happen is a ducking. Even after becoming expert as a land flier, flying has to be confined to the aerodrome, or to a very few places where there are suitable open spaces to land, and flying across country has to be done at a great altitude in order to pick a suitable spot in case it should become necessary to descend.

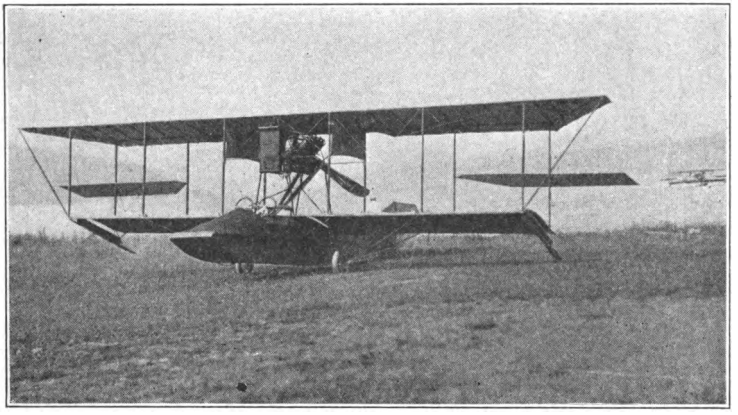

FIG. 2.—CURTISS FLYING BOAT.

How different this becomes with the hydro-aeroplane, for directions are practically unlimited; there is always a safe and unobstructed landing place, hence it is not necessary to fly at a greater height than a few feet nor to leave the water at all; and the factor of safety is increased a hundred per cent. How many people who desire and who can afford to take up aviation own homes or at least spend the summers on the water? A conservative estimate is seventy-five per cent., and of these a majority own fast motor boats, the speed of which does not average over twenty-five miles an hour at the highest limit. Can you imagine how much more pleasure would be derived from a hydro-aeroplane making from forty to fifty miles an hour on the

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water and from fifty to sixty miles in the air? This means that many people living on the Sound could make the trip to New York in one-third of the time otherwise required. Of course, the objection will be raised that the hydro cannot be used in rough weather, and that it is hard to find a place where it can be suitably housed. It has been my experience that the "Flying Boat" can be used in weather as rough as that in which one would ordinarily care to operate a small motor boat. A suitable shed for easy handling can be built as cheaply as a boat house, and in case of a sudden storm the machine can be run up on the beach and staked down without fear of injury. It is the

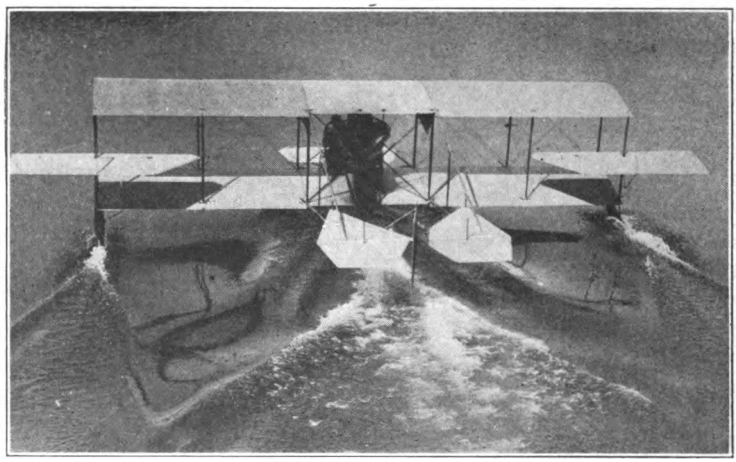

FIG. 3.—REAR VIEW OF FLYING BOAT TRAVELING 25 MILES PER HOUR AS MOTOR BOAT.

practice in both the Army and the Navy where tent hangars are used, to stake the machines in the open when a very heavy blow is expected. In one instance our machines thus safely rode out a sixty-five mile gale, and remained in the rain for three days, the only precaution taken being to cover the motor carefully.

Has it ever been brought to your notice that over eighty per cent. of the aviation fatalities are the results of accidents—or as the newspapers call it "loss of control"—when the aeroplane is at an altitude of two hundred feet or less? Investigation generally shows that the accidents result from air eddies close to

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the ground, from attempts to reach a safe landing place, or attempts to avoid obstacles. Newspaper reports generally state that the aviator lost control at from two thousand feet down to two hundred, making the altitude as great as possible, for sensational headline purposes perhaps. Investigation will show that, with very few exceptions, the aviator retained full or partial control until the aeroplane was comparatively near the ground, and in nine out of ten cases no fatality would have resulted if the aeroplane had been over water.

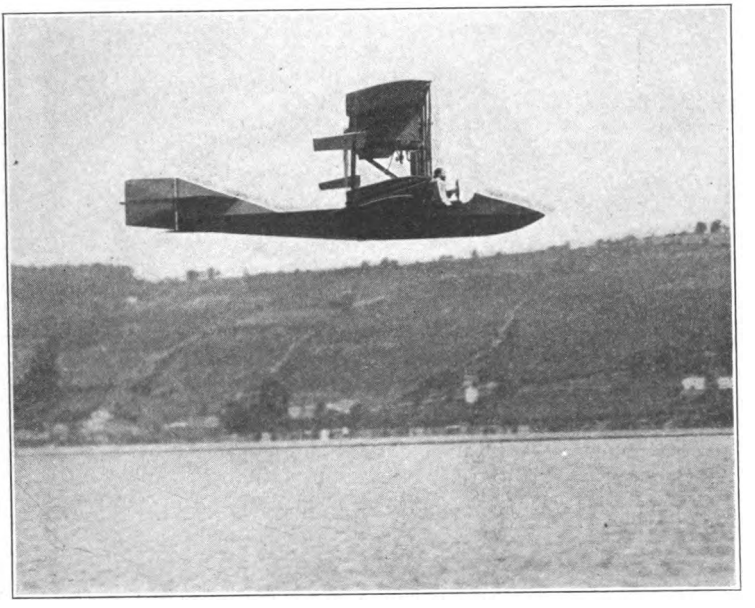

FIG. 4.—SIDE VIEW OF FLYING BOAT.

I will cite a few instances in an attempt to uphold this statement. Dr. Clark at Nassau Boulevard, Moisant, Hoxey, Badger, Peck, Ely, and the two fatalities at College Park, were the result of the machine diving straight to the ground. At the Navy Aviation Camp we have had two accidents which are parallel to the above, and in neither one did the aviator receive the slightest injury. The first occurred during experimental work with a compressed air launching device. With the engine running full speed, the machine was given an impulse of two hundred and

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sixty pounds, and owing to imperfections in the device and a side wind, made a corkscrew dive and struck the water at an angle of seventy degrees. In the second case, one of the officers under training came in before a twenty-mile wind at an altitude of three hundred feet, and attempted to glide for a landing, but for some unknown reason the throttle remained wide open. He tried to force the machine on the water, misjudged the distance, struck on the nose of the main pontoon at an angle of twenty degrees, capsized and wrecked the machine. In both of the above cases the aviator was carried under water with the machine.

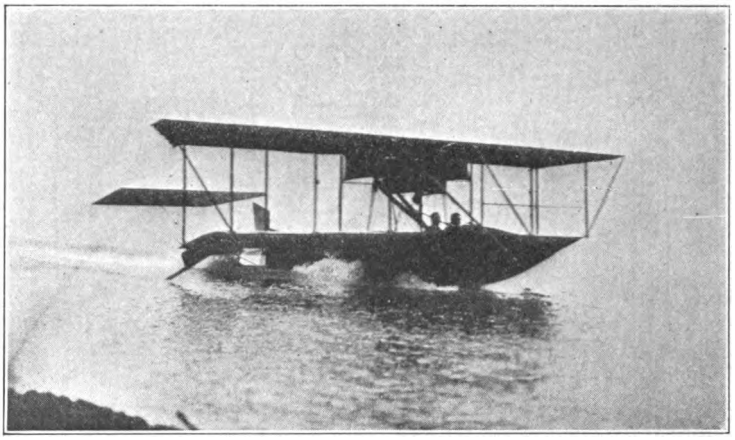

FIG. 5.—TRAVELING AS A MOTOR BOAT.

At the time the latter aeroplane struck the water it was going easily eighty miles an hour.

In the cases of Walsh and Ralph Johnstone, full control was apparently lost at a great altitude, but in both cases the aviators were seen struggling to regain control until comparatively close to the ground, and then the aeroplane apparently slid sideways. We have had four accidents similar in a way to these, in only one of which was anyone injured in the slightest, and in three of the accidents there were two persons in the machine. Two were caused by the attempt to turn too close to the water, with the result that the machines struck on one wing and were wrecked. One was due to stalling on a turn at a height of one hundred

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feet and sliding down sideways. The other resulted from a bad gust when turning to the left away from a twenty-five mile wind, at an altitude of two hundred feet. In this instance the machine was banked to such an angle by the sudden gust that although headed down at an angle of twenty degrees and the power kept on in an effort to regain control, it would not respond and struck on the left wing at this angle. Only one person was in the machine and the normal speed in this condition is sixty-five miles an hour. With the twenty-five mile wind behind and the machine on a glide, the speed was well over ninety miles an

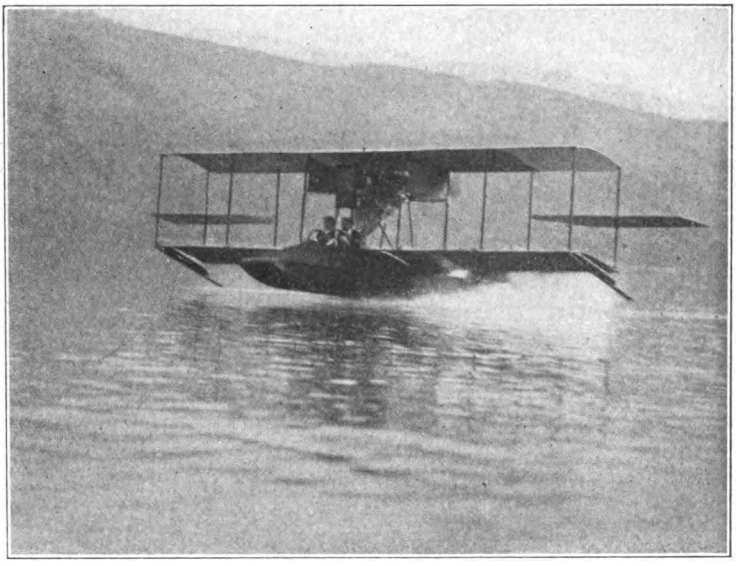

FIG. 6.—TRAVELING IN WATER, 50 MILES AN HOUR.

hour, and yet the aviator escaped with a few bad bruises and a twisted ankle. In all of the above cases both the aviator and the passenger were carried under water by the machine.

It was thought that the hydro-aeroplane would prove a great timulus to the aeroplane industry, and thereby to the development of aviation, owing to the large factor of safety introduced. Up to the present this has proved true only to a limited extent. Few people realize the immense expense involved in the experi-

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mental work in the development of aviation, and that the men seriously interested in this work are men of comparatively small means, to whom financial support is an absolute necessity. Every one points to the immense sums made in the early days from exhibition work, and to the high price of aeroplanes relative to the actual cost, taking it for granted then that the established aeroplane industries are bonanzas of wealth. They do not think of the years when there were no returns, the cost of experimental work, the extra cost due to the rapid advance of

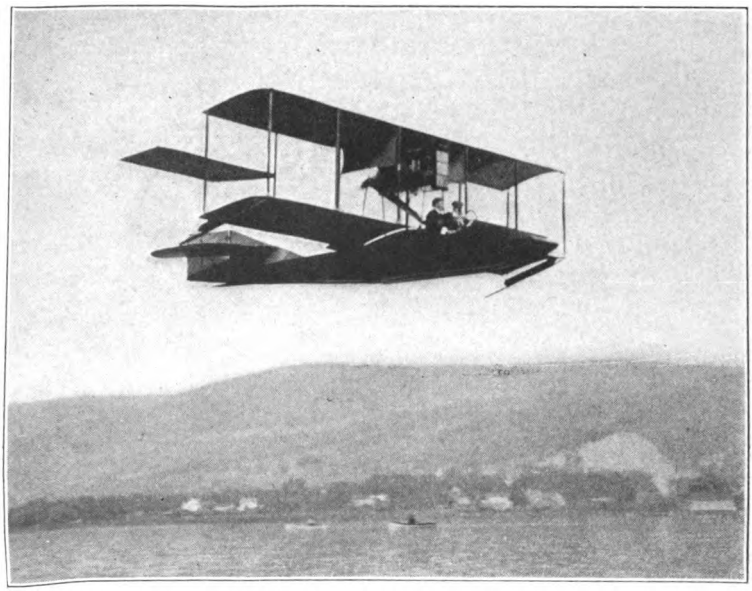

FIG. 7.—FLYING AT 60 MILES PER HOUR.

aviation which makes it impossible to standardize any particular design, and the very small market for aeroplanes. Nearly all the exhibition companies lost money last year, and hence the sale of aeroplanes nearly ceased, as exhibition fliers had been practically the only purchasers in this country. It is true that a few machines were purchased by the Government, but the number was so small as to be negligible, and my information is that the Curtiss Company was the only one that sold machines abroad.

Before taking up the Flying Boat, I wish to touch on some

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of the recognized hydro-aeroplanes. The first developed—the Curtiss—is shown in Fig. 1. Its essential features are a narrow single pontoon and rigid balancing pontoons at the wing tips. This was the first machine to rise from, and land on, both the land and the water, the first to be hoisted aboard a battleship, the first to be launched in flight by means of a compressed air catapult, and holds the world's endurance record of hydro-aeroplanes, six hours and ten minutes.

The Burgess Co. & Curtis, Marblehead, Mass., delivered in January a Burgess-Wright machine to the Army for coast defence, which attained a speed of fifty-nine miles an hour. This was the first company to use the catamaran or twin pontoon type, with steps, and to employ aluminum and copper floats. This company tried out experimental machines over water, as was done with the tractor developed for the Army. It built the experimental machine for Howard Gill, with twin independent power plants, the only machine to fulfill the requirements of the Gould *Scientific American* Contest. A similar type was used by Frank Coffyn in his flights over New York Harbor.

The main features of the Benoist Hydro, which was used by Jannus in his flight from Omaha to New Orleans, are the tractor with inclosed body, and very large main pontoon.

The Glen Martin Hydro is practically the same as the Curtiss, and has been doing good work on the Pacific Coast.

Now to come to the subject of the development of the "Flying Boat." It was in July, 1911, that the first hydro-aeroplane, a Curtiss, was delivered to the Government. Through the courtesy of Mr. Curtiss, and owing to the fact that the Navy aerodrome was not completed at that time, this machine was kept at Hammondsport and experimental work conducted there in developing minor details, and in thoroughly trying out the machine to determine what its limitations were. We found to our surprise that it handled as easily as a land machine, and that it banked and assumed a gliding angle quite as easily; then we began to note the defects. The machine did not leave the water in a calm with the weight we thought necessary; in rough water we occasionally broke a propeller; if there were any sort of a sea we would be wet to the knees; it was easy to make a bad landing especially

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in a side wind; it did not handle as well as we desired on the water, and it was not fitted with a self-starter.

Mr. Curtiss took hold of these problems as they presented themselves and solved all of them before the machine was sent to Annapolis in September. Then he wished to know what sort of a machine the Navy wanted, but our experience was limited, and we only suggested a boat hull with inclosed hood for aviator and instruments. It was at this time that he outlined to us his idea of the "Flying Boat"; and although we listened with respect and enthusiasm, we feared that for once he was attempting the

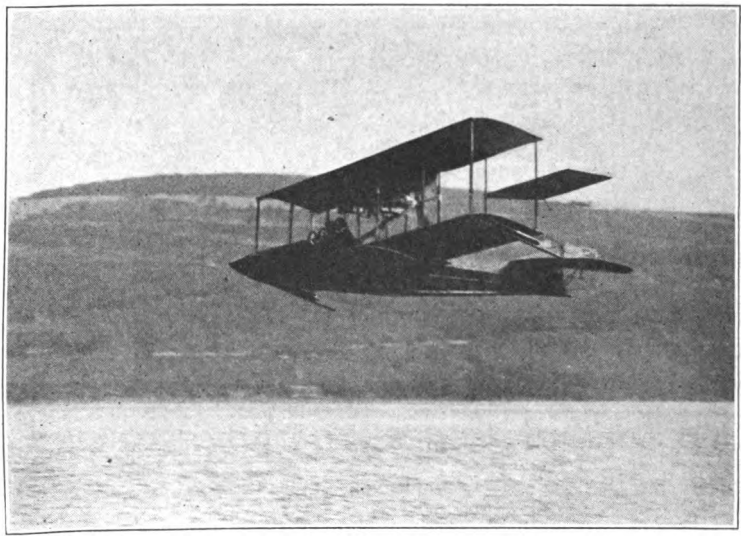

FIG. 8.—BEFORE THE WIND AT 75 MILES PER HOUR.

impossible, for it must be remembered that at this time, with the exception of Mr. Curtiss himself, the Navy fliers were the only persons operating a hydro. As a matter of fact, we were so skeptical that I am afraid that we did not give the matter serious thought.

It was not until we arrived in San Diego, Cal., early in January, 1912, that we again thought of the matter, and only then when we saw the model of one of the boats under construction. This was later fitted to one of the Curtiss speed machines, being

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the only aeroplane available at the time. These surfaces are small and very flat, and hence known to be inefficient for the weight to be lifted. A double tractor was decided on, to be chain driven, for it was thought that the efficiency gained from geared down propellers of large diameter and pitch would in a measure overcome the inefficient plane surfaces, at least enough for experimental purposes. The motor used was a standard Curtiss 50-60 h. p. This was the first development. The bow of the boat extending as far back as the front edge of the plane is the same as that used in the old pontoons. The Curtiss bamboo tail is the same, but the boat is ten feet longer, and the operator's seat is well back between the planes. The engine is low and easily accessible to either the operator or passenger. Trouble was experienced with the chains from the start, and they were continually breaking, which led to the conclusion that the chain drive was not dependable for the amount of power needed.

The arguments in favor of this type were as follows: Efficiency due to propellers of large diameter and pitch and hence less power required with the reduction of power, less weight, owing to the lower consumption of gasoline and oil; low center of gravity; accessibility of the engine to the operator and passenger; greatest clearance from the water for the propellers, and hence danger of breaking them reduced to a minimum; protection of the aviator from wind and water. Many runs over the water and several short jumps in the air were made with this machine, but difficulties with the chain drive and other more important disadvantages led to the abandonment of the type. Some of the disadvantages were that the pilot was in the rear of and close to the exhaust, which was hard on both the hearing and eyesight; the chain drive was unsatisfactory; the line of vision was very much obscured; the safety factor was greatly reduced, for in case of a sudden plunge into the water, the operator would be thrown through the framework, chains, or propellers, and probably become entangled therein.

The next experiment reverted to the direct-drive propeller, and in order to obtain sufficient clearance from the boat it was necessary to allow the engine to extend above the top plane. Experiments with this type showed that the center of thrust was too high; that the tail stabilizers and controls made fast to the boat

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were placed too low, and were easily damaged by the waves, though this position greatly improved the manoeuvering qualities of the machine; that a hood was necessary for the bow of the boat to keep the operator dry; that a step would have to be used in order to allow the boat to leave the water easily; and that the boat would have to slant upward towards the stern, because at high speeds the stern dragged and brought undue strains on the rear controls as well as tending to hold the boat on the water.

By this time sufficient data had been obtained to warrant the construction of a machine. Special planes were manufactured with a different camber and different curvature, and the chord

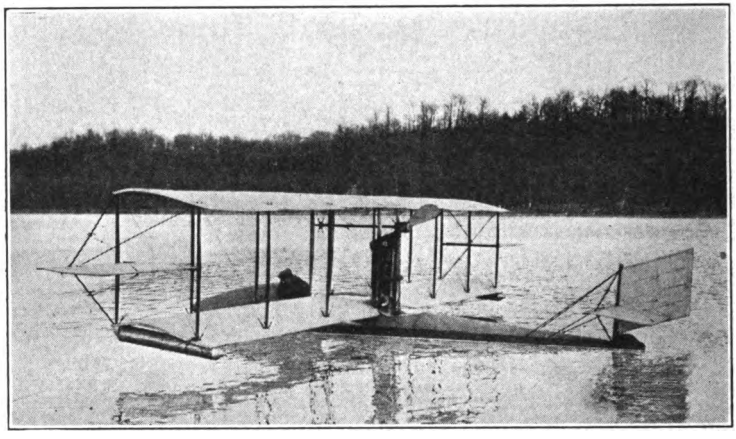

FIG. 9.—BENOIST FLYING BOAT.

and separation of the planes were increased. Triangular extensions were added and given a slight diehedral angle, and these with the increased amount of surface due to the larger planes, greatly increased the lifting capacity. The greater separation of the planes allowed the engine to be properly mounted, and at the same time give the propeller enough clearance. A step was built in the boat which enabled it to leave the water more quickly, and vent tubes were led from abaft the step to the top of the boat, to relieve the suction which was found to be appreciable when running at high speeds. The front control was used for the first experiments but this was later discarded as useless.

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Practically the entire development work was accomplished with this model after innumerable experiments. The factors hardest to determine were the location, shape, and depth of the step in the boat, the lines of the body of the boat abaft the step, and the location and design of the rear controls. A change in any of these factors generally resulted in a change of all of them, which was instructive but tedious.

All of the determining factors had been obtained, but surfaces of a different camber and curvature and the trailing aileron were used and the size of the boat was increased. The hood for the protection of the aviator was developed on this model, and also the proper location of the rear controls. These were so placed

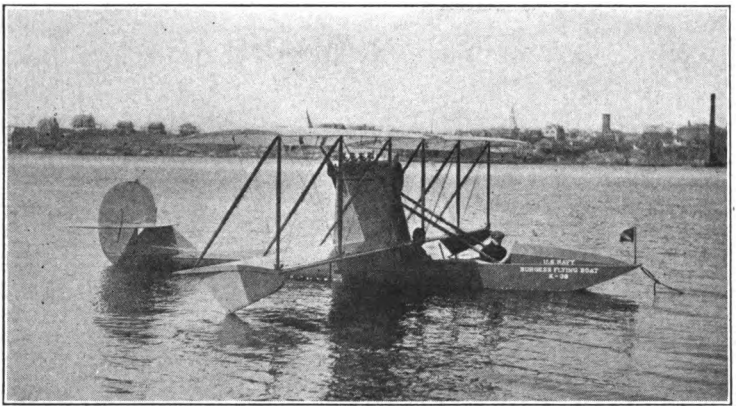

FIG. 10.—BURGESS FLYING BOAT.

that when the machine was running on the water, the air rudder was used as a water rudder, and at the same time the other controls were raised so that they would not be endangered by the waves. No advantage was found in the use of the trailing aileron and it was abandoned.

The original model was again rebuilt and the results of all the experiments embodied in it. This was then tried out at Hammondsport over Lake Keuka, under all conditions of wind and weather obtainable there, and was found to handle perfectly. I tried the machine out at this time and was more than pleased with it, but still not thoroughly convinced that it would

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handle well under bad weather and bad water conditions, and suggested that it be shipped to some place where these could be obtained. As a result the machine was shipped to Charlotte, a suburb of Rochester, N. Y., on Lake Ontario, and for the first time I prayed for wind and rough water before flying, but even that brought no results for five days. Then there came a northeaster and after this had subsided the water remained rough, about a four-foot sea, and the wind was blowing between twelve and fifteen miles an hour. The machine was then given a thorough test, and found to be dry on the water, easily handled in the water, and satisfactory in every respect.

Some of the tests were: running on the water at full speed headed into the wind and sea; with wind and sea following; in a cross sea; turning both into and away from the wind, at both high and low speeds. Next came rising from and lighting on the water, with the wind ahead, astern, and on the beam. This was easily accomplished, but would have surely meant a spill in the old type hydro-aeroplane. The final and hardest test was stalling the machine and allowing it to drop from low altitudes, to determine if it was structurally strong enough. This was started very close to the water, but the last drop was from a height of nearly fifteen feet, and nothing was strained or broken.

Here was tested the invention of Mr. Curtiss for enabling the aeroplane to ride safely on the water with the engine stopped and a strong wind blowing. If some means were not employed, when there is both wind and sea, and the machine is dead in the water, the wind will get under the weather wing and cause the machine to capsize. I have referred to the triangular extensions at the ends of the upper planes. These extensions are hinged and connected to a lever back of the operator's seat, and a movement of this lever drops these extensions to an angle of forty-five degrees with the main planes, and rigidly holds them in that position. Now the pressure of the wind on the windward wing will be on top of this extension and tend to keep this wing down. On the lower wing it will be under this extension and tend to hold this wing up. Upon trial it functioned well and kept the machine on practically an even keel.

Immediately after these tests the Curtiss Aeroplane Company

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Flying Boat was offered to the public, and the construction of one for the Navy and one for the Army was started. For his development of the Flying Boat, Mr. Curtiss was awarded the Collier Trophy by the Aero Club of America, for the greatest achievement in aviation during the year 1912.

In Fig. 2 is shown the machine delivered to the Navy. Note the wheels for use on land, the high hood for the protection of the passengers and instruments, the hand crank above the seat for starting the motor, and the solid appearance of the whole machine.

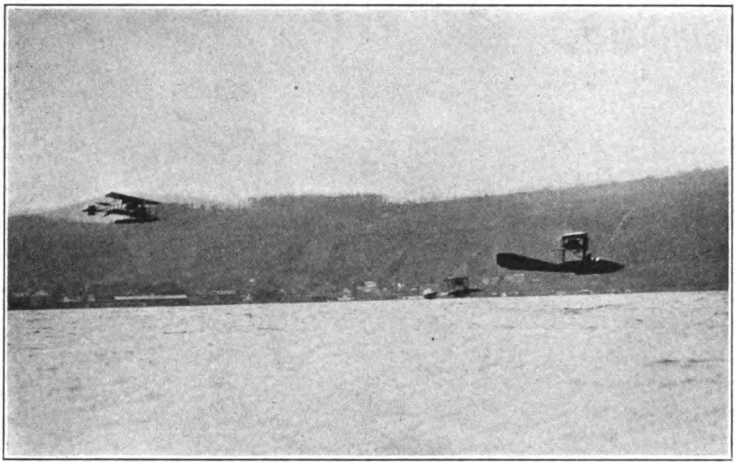

FIG. 11.—RACE BETWEEN HYDRO-AEROPLANE AND TWO FLYING BOATS.

As to the general characteristics of this machine: In appearance it is a blue or slate color, the same as the war color used on battleships, which wears well and gives the machine a neat clean look. It is one of the first machines in this country that has been scientifically built—that is, extra strong in the engine section where strength is needed, and tapering to the wing tips where there is less strain. Heretofore it has been the custom to make the wing beams and ribs the same size and strength as those of the center section, with the result that the latter were overloaded. The operator's and passenger's seats are low down, with a clear field of vision both ahead and below, well protected

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from both water and wind. There is a feeling of security similar to that of riding in an automobile. The machine can be operated from either seat, and by simply turning a knob between the seats either set of controls can be disconnected, but not both sets at the same time. This gives the person not driving a chance to rest or to make observations without the controls interfering with him.

The instruments, which are mounted under the hood and well protected from the wind and weather, are as follows: Electrical speedometer, showing revolutions of the engine; chart roll; compass; inclinometer, to show climbing or gliding angle; gasoline and oil gauges; clock; barograph. All of these instruments are visible to both operator and observer.

In order to keep the weight as low as possible and to reduce the head resistance, the main gasoline tank (42 gallons) is situated in the hull of the boat. There is an auxiliary feeder tank, eight gallons capacity, attached to the side of the engine bed, in order to get a head of gasoline for the carburetter. Gasoline is pumped from the main to the feeder tank by means of a plunger pump driven from the water pump shaft, there being an overflow to the main tank which takes care of any excess. In case the pump should break down, a small electric light under the hood is automatically lighted as soon as the gasoline in the feeder tank drops to four gallons. Then it is only necessary to close the vent on the main tank, and by means of a hand air pump accessible to the operator, put pressure on this tank, which forces gasoline to the feeder tank. For rising from and landing on the water when it is not advisable to release the controls even for an instant, the engine is controlled by a foot throttle; but since in the air this may become tiresome, especially on a long glide, a hand throttle is fitted for this use. Between the seats and accessible to both passengers is the lever for operating the wheels, which fold up close under the planes. This is necessary, as the machine will not rise from the water if the wheels are allowed to drag, and once in the air the head resistance is greatly reduced if the wheels are raised. When it is desired to alight on the land, the lever is simply released and the wheels fall into place and are rigidly locked, and then a landing can be made on fairly

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rough ground as easily as with an ordinary aeroplane. The engine is fitted with a muffler which adds greatly to the comfort of the aviators.

As to the handling of the Flying Boat: It can be turned on the water in shorter space than a motor boat of the same length, but it turns better at low than at high speeds, because in the former case the boat settles in the water, and the air rudder becomes an effective water rudder. In the air it handles as easily as an aeroplane, on banks, turns and glides, and is very much steadier. George Beatty, one of the veteran Wright fliers, made his first flight in a Flying Boat, and incidentally in a Curtiss machine, a short time ago. After the flight he expressed his opinion that it was steadier, there was less vibration, and that it was more comfortable than any machine he had ever been in, and also as easily handled. At no time does the operator or passenger become wet by the spray as was the case in the old hydro, nor is there any chance of breaking a propeller due to striking the water, or coming to grief as the result of landing in a side wind. When flying at the Washington Navy Yard, it was the common practice to stop the machine in the river, have a motor boat come alongside and transfer passengers, and start again without outside help. The same thing could be easily done if it was desired to tie up to a buoy. In brief, in these respects it is brought into a class with the motor boat.

In the accompanying illustrations, Fig. 5 shows the "flying boat" starting out as a motor boat. Fig. 3 shows a rear view of the "flying boat" starting out as a motor boat at twenty-five miles an hour. The "boat" is shown in Fig. 6 with the planes slightly raised. With her tail only resting on the water the "boat" is travelling at fifty miles an hour. In Fig. 7 the machine has risen from the water and is travelling at sixty miles an hour. Fig. 4 shows the contour of the "boat" in full flight. In Fig. 8 she is returning before the wind at seventy-five miles an hour.

Other designs have been and are being produced in this country, but so little flying has been done with any other type up to the present time, that it is hard to criticise them impartially. The Donnet-Leveque was developed abroad about the same time that the Curtiss Flying Boat was developed here. This machine is

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very similar to the Curtiss, except that it is designed for one passenger only, and is very light, the total weight with fuel being under one thousand pounds. The Gnome motor is used. It climbs very fast, nearly three hundred feet a minute, which is partly due to the very light boat used. This boat will not stand use in rough water, as was proved by the flights made by Beaumont; and in every instance where rough water was encountered the boat was wrecked.

The Benoist Company have lately placed a Flying Boat on the market, which is shown in Fig. 9. The power plant is placed in the boat, the propeller being chain-driven, but it seems that this would place the center of gravity too low. In describing the boat, Mr. Robinson, who has been operating the machine, states that it banks itself without use of the ailerons, and that in a puffy wind it oscillates to some extent. The two seats are placed tandem, and the Roberts motor is used at present.

Fig. 10 shows a Flying Boat now being built for the Navy by Burgess Co. & Curtis, which develops a speed of about forty-five miles per hour on the water and sixty-eight miles in the air. It is equipped with a 70-h.p., eight-cylinder, air-cooled Renault motor and has a spread of forty-six feet in the upper plane and thirty-eight feet in the lower plane, the planes being covered with Burgess specially prepared linen. The contruction is interesting on account of the fact that it is the first aeroplane ever built using the warping system, having the lower plane constructed rigidly and the entire surface of the upper plane warping.

This plane is staggered forward of the lower plane and is supported by one central steel tubular beam, running through the center of the plane, just forward of the center of pressure. By the removal of the four bolts, the aeroplane can be released entirely from the boat section, and by the removal of two other bolts the rear section of the boat can be separated from the front section. The wings fold almost automatically together for shipment. It is estimated that the machine can be entirely dissembled by four men in from twenty to thirty minutes.

The Washington Aeroplane Co. has developed a Flying Boat, now being tried out at Washington, which is well constructed and promises well. The Gyro motor is used. One of the chief

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features is the long trailing edge of the plane, which is intended to give great lift at the start, and high speed once in the air. Mr. Loening, of New York City, has experimented with the Flying Boat for the past four years, and the engineering features of this machine are among the best yet developed.

These are only a few of the manufacturers interested in this subject, but the enthusiasm which is being exhibited bids fair to make the Flying Boat a popular sport before the coming summer is over.

In conclusion I wish to show a picture of a race between a hydro and two Flying Boats (Fig. 11). On crossing the finish line both boats have forged ahead of the hydro which they are leaving far behind. This race was over a three mile course, and was more exciting than any other race I have ever witnessed.

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SAFE FLIGHT AND AUTOMATIC STABILIZATION OF AEROPLANES.*

By Elmer A. Sperry.

It is not thought necessary to dwell upon the desirability of complete stabilization of aeroplanes. This subject has been approached from no less a standpoint than the one of complete automatic flight, barring the single item of direction in azimuth.

In addition to all the longitudinal control, the apparatus dealt with herein extends to the automatic banking to the point of zero "skid," either inwardly or outwardly, in turning curves. Air is a very unstable medium, and the development of the heavier-than-air machine has shown us that the atmosphere is in a constant state of turmoil, rendering its navigation perilous. The aviator must work constantly to maintain the stability of the machine about all three axes. With the present machines very long flights are nearly beyond the endurance of the aviator, and even short flights are difficult when the weather is at all bad. Many attempts have been made to solve this problem, and we will touch on a few of these, which may be divided into two classes.

First, non-gyroscopic, of which the Wright stabilizer is typical. This is operated by a pendulum or pendulous mass working either alone or in conjunction with small actuating planes, using a Servo motor to manipulate the control. No record of the performance of this apparatus has even been published, and it is doubtful if a pendulum can be employed, owing to its liability to synchronize with some of the movements of the plane, and thus very greatly disturb the equilibrium and render the results unreliable.

A diagramatic view of one of the Wright controls is shown in Fig. 1. The Doutre has been adopted to some extent in France. This is shown in Fig. 2. The Servo motor is here operated by a

* A paper presented at the 319th meeting of the New York Electrical Society, held April 17, 1913, in the Engineering Societies Building, New York.

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pendulous weight in the 1913 model, and a sliding weight in the 1912 model, acting in conjunction with anemometer disk.

Attempts to use the gyroscope as a source of control have been largely handicapped from the fact that its application has not always been intelligent—that is, the true nature of the gyroscopic reactions has not been recognized. A single gyro is found to be responsive to all prime components of universal compound motion. In this way disturbing influences are introduced, rendering the operation unexpectedly erratic and unreliable. These attempts have in the main been abandoned. This difficulty has

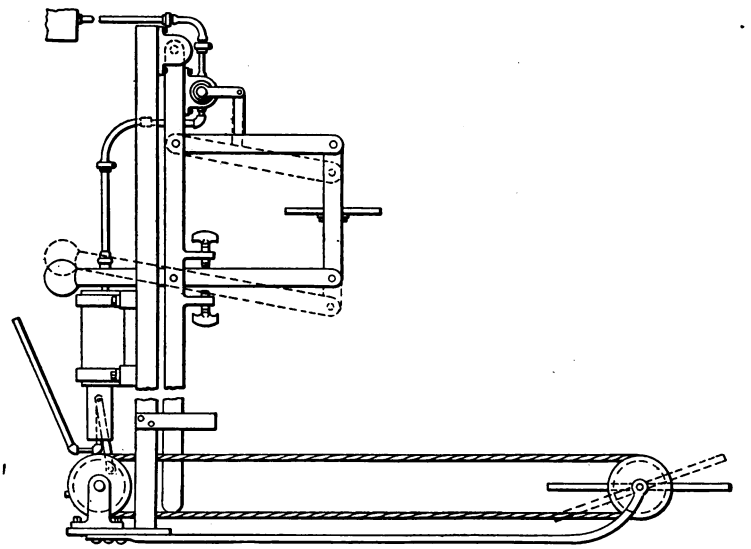

FIG. 1.—DIAGRAM SHOWING WRIGHT CONTROLS.

finally been overcome and a gyroscopic equipment is now available which will respond to only one of the three components, eliminating disturbances from the other two. Thus, any axis may be selected, whereupon the gyroscope will constitute an extremely rigid base line and respond only to the motions about such axis, and remain entirely unaffected by others, thus constituting an extremely reliable and dependable starting point for many useful applications of the gyroscope, which have been heretofore impossible. To illustrate this we will examine in passing

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several recent successful applications of the gyroscope upon which I have been engaged and which are now in regular course of manufacture.

Fig. 3 represents the gyro compass. Fig. 4 represents the master gyro compass card, showing general view from the top. These compasses have now been adopted as standard by the United States Navy and practically all the larger battleships and submarines are being equipped as rapidly as possible.

Cases where the gyro is employed as a base line may be illustrated by the Roll and Pitch Recorder, shown in Fig. 5. Here

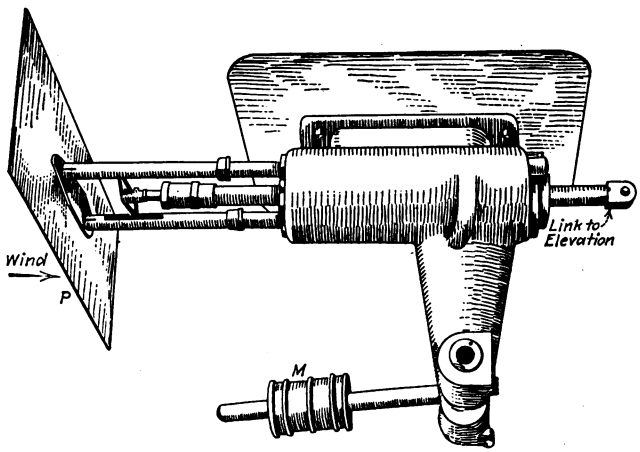

FIG. 2.—DOUTRE STABILIZER.

each of the two gyro equipments are responsive only to motion about a given axis, and entirely unresponsive to motions about every other axis. Gyros in this class of apparatus cannot "tumble," as is found to be the case with the single gyro employed in the Whitehead torpedo, for the reason assigned above.

With reference to gyroscopes being used as stabilizers, we may cite their application to optical instruments, where this peculiar equipment is used to stabilize artificial horizons.

The stabilizer shown in Fig. 6 is used in connection with ordnance apparatus and covers a number of applications. This equipment is also used to operate a number of instruments, among which is an important new application to the clinometer.

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Under this heading of the use of the gyroscope for stabilization, we have the stabilization of ships. Fig. 7 shows the most powerful gyroscope plant that has ever been constructed. Fig. 8 shows the middle section of the four-funnel ship with this plant installed between the life boats in the figure. Fig. 9 is a sample

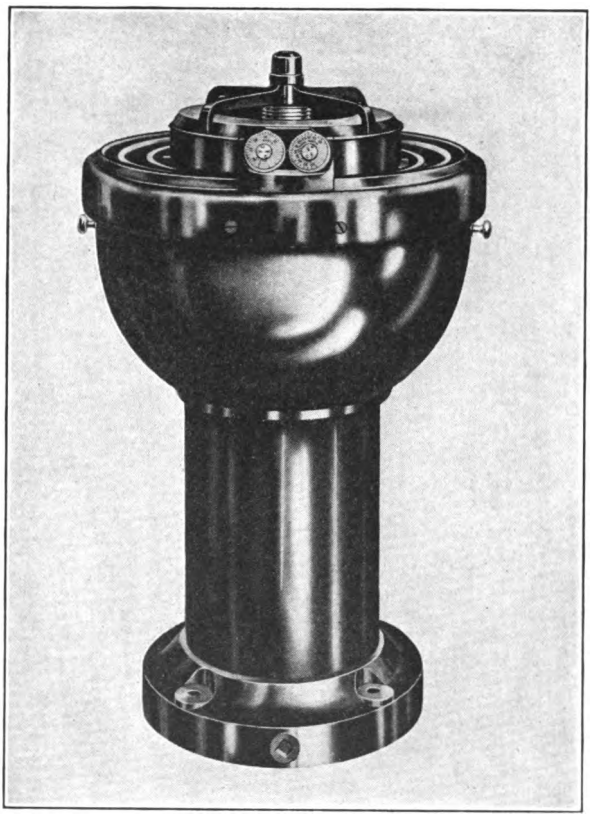

FIG. 3.—GYRO COMPASS.

of the rough stabilization, the ends showing the sea running at the time.

Coming now to the former attempts at gyroscopic stabilization of aeroplanes by a single gyro, we have that of Mr. Beach, who employed a gyroscope which I made for him. This was an attempt at direct stabilization of the

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machine through gyroscopic reactions. Also a mechanism devised by the well known engineer, Ferranti, of England, Fig. 10. Fig. 11 indicates a recent attempt which is something similar to Ferranti's in that two gyroscopes are employed. None of these devices has come into commercial use, so far as recorded.

In connection with the gyroscopic stabilizer upon which I have been engaged for some time, I would say that a year ago the appa-

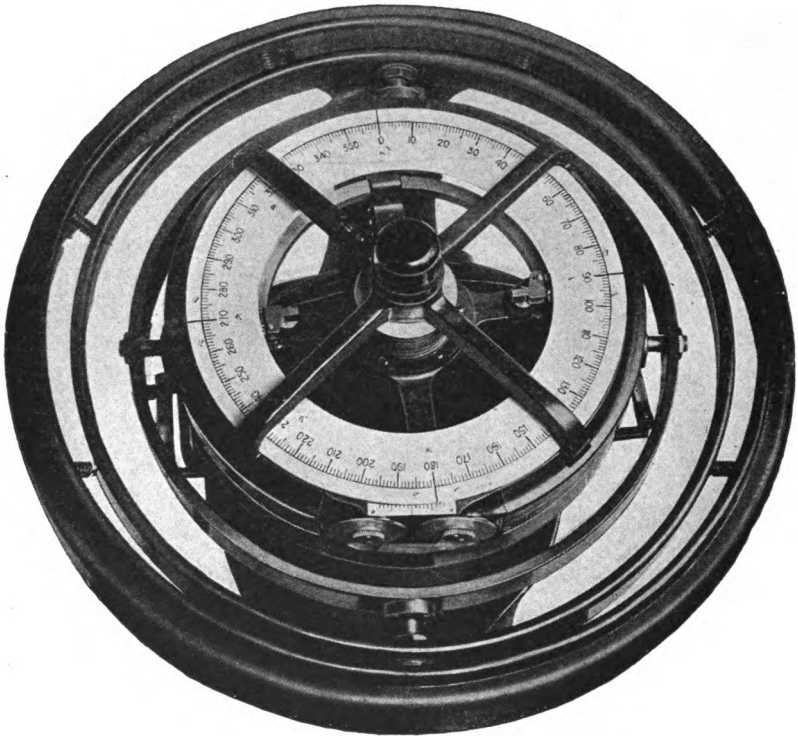

FIG. 4.—COMPASS CARD, FROM HELMSMAN'S POSITION.

ratus was completed and installed on a Curtiss aeroplane in New York. Some progress was made there, and then improvements were introduced and tests were continued all winter at San Diego, under the eye of Mr. Curtiss and the officers of the Aviation Corps of the United States Army. Progress was there made to the extent of practically the solution of the perplexing problem of lateral stability, with its difficult factor of automatic banking,

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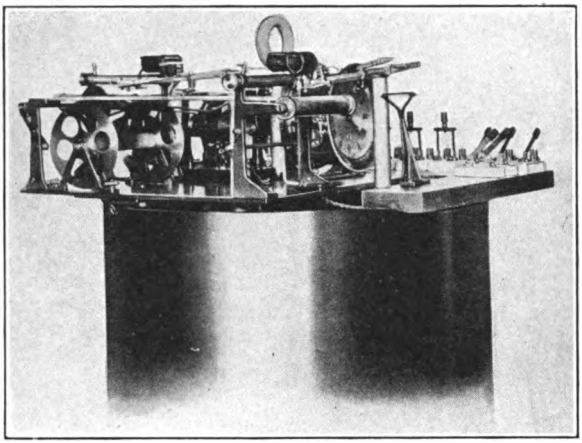

FIG. 5.—APPARATUS FOR RECORDING ROLL AND PITCH OF VESSEL.

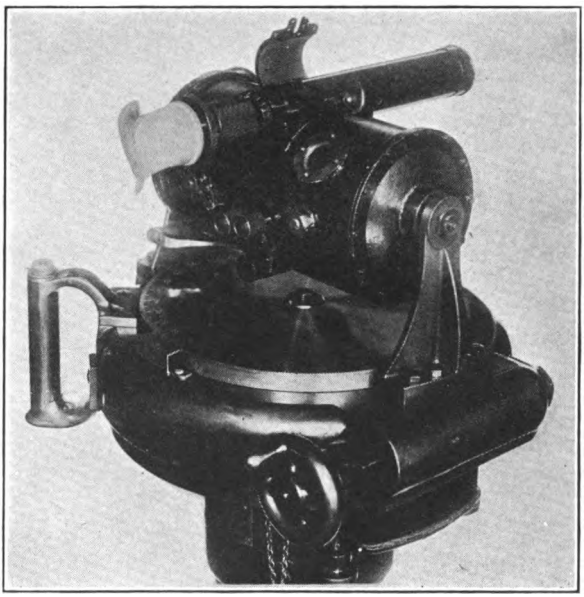

FIG. 6.—A CASE OF CONTROLLED STABILIZATION.

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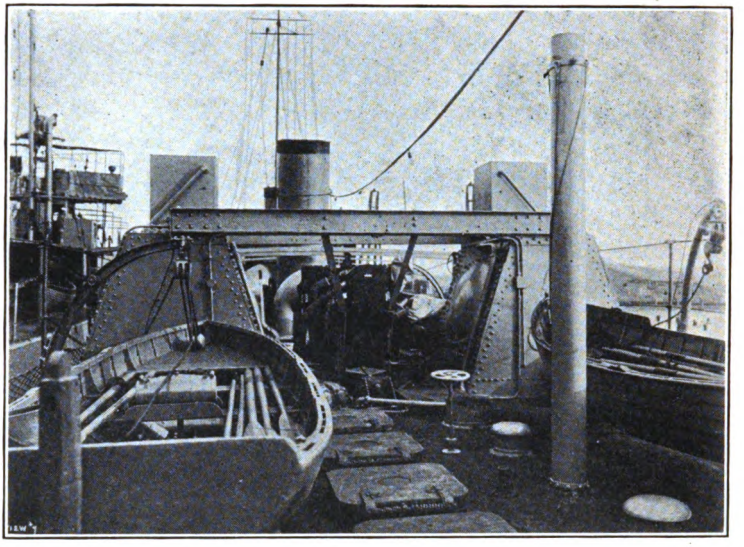

FIG. 7.—THE MOST POWERFUL GYROSCOPIC STABILIZING PLANT EVER CONSTRUCTED.

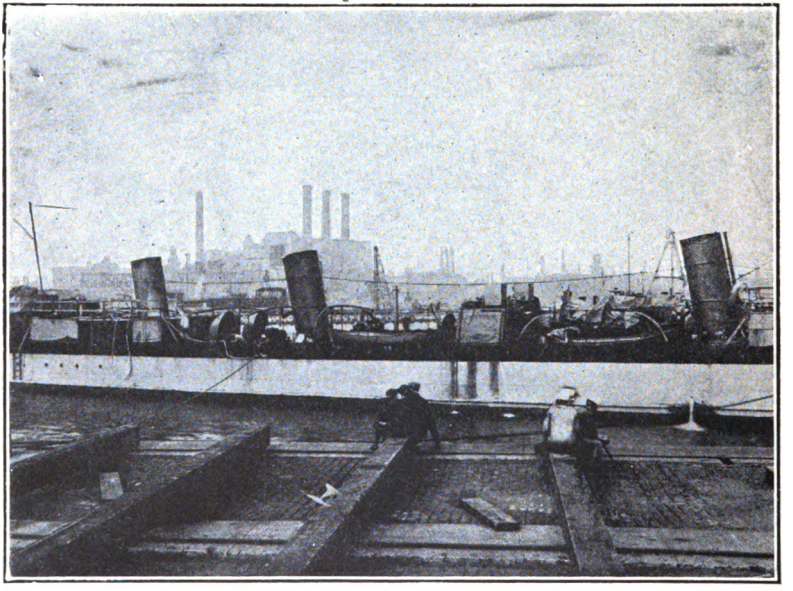

FIG. 8.—MIDDLE SECTION OF SHIP, SHOWING GYRO PLANT.

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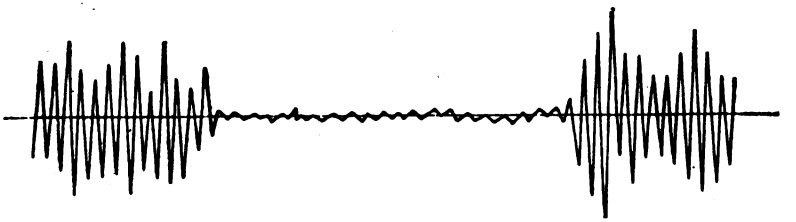
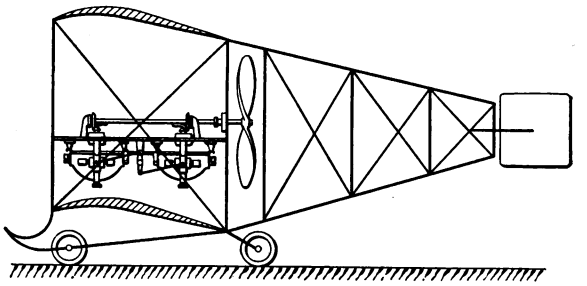


FIG. 9.—ROUGH STABILIZING CURVE. ENDS INDICATE SEA RUNNING AT THE TIME.



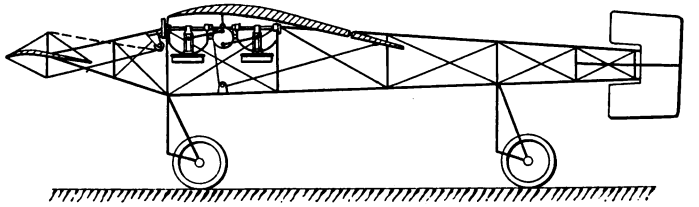


FIG. 10.—FERRANTI GYROSCOPIC APPARATUS.

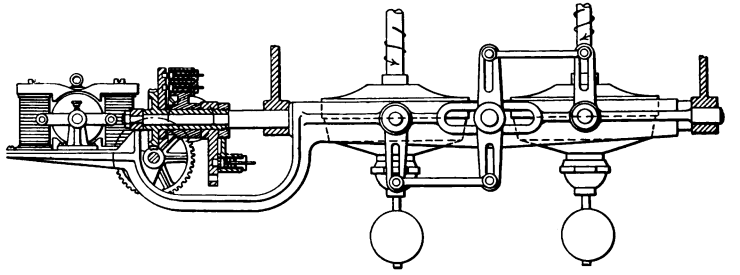


FIG. 11.—A RECENT DEVELOPMENT, USING TWO GYROS.

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which must at all times be proportional to the radius of the curvature, speed and a number of other factors, all of this while not in the least interfering with the full functioning of the stabilizer in neutralizing bad effects from pulls, upward and downward trends and general atmospheric disturbances encountered.

Each aeroplane stabilizing equipment comprises a combination of devices for maintaining longitudinal stability and a combina-

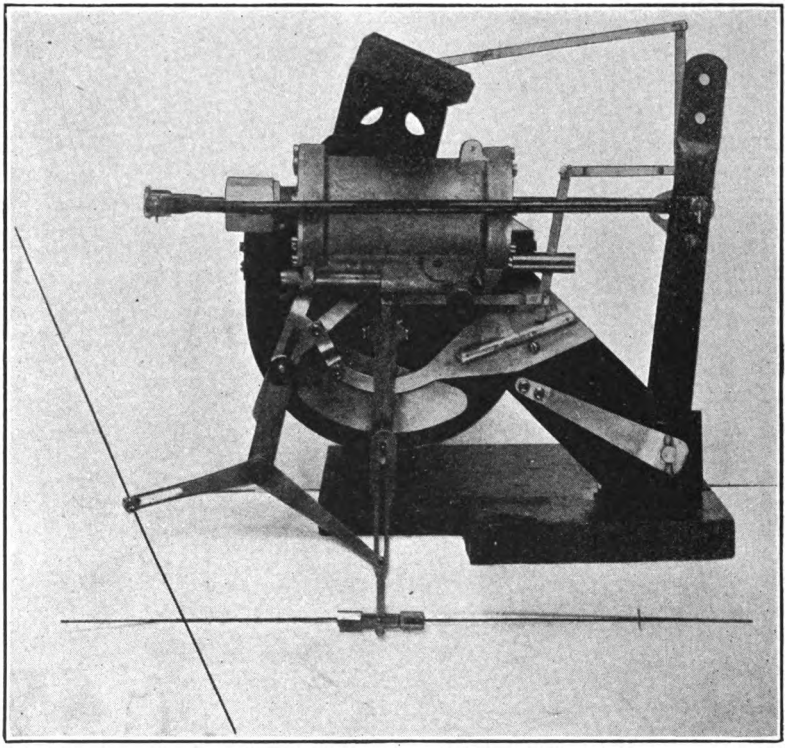

FIG. 12.—SPERRY LATERAL STABILIZER.

tion for maintaining lateral stability. The longitudinal stabilizer uses three directive factors for controlling the movements of a pilot valve, which in turn controls a compressed air cylinder operating a piston attached to the horizontal rudders. The controlling factors are: First, the gyro which through the pilot valve operates the horizontal rudders against tendency to tip about the

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horizontal axis; second, an anemometer which operates the pilot

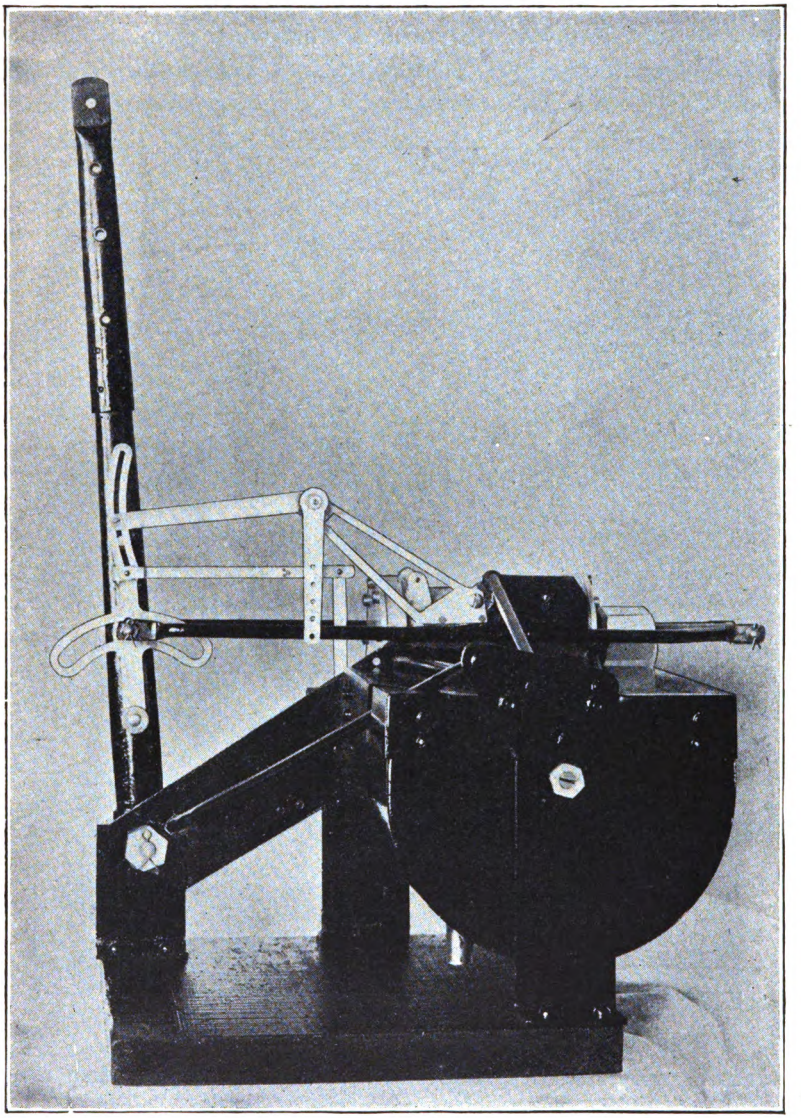

FIG. 13.—SPERRY LONGITUDINAL STABILIZER.

valve to volplane the machine in case the speed drops below the critical speed necessary for sustaining the plane; third, a hand-

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setting device which permits the aviator to set the stabilizer for any inclination of climb or descent. The air platen further acts to adjust the throw of the levers, so that when running at slow speeds a small tipping is counteracted by a suitable throw of the rudders. This is made necessary by the fact that the plane is, of

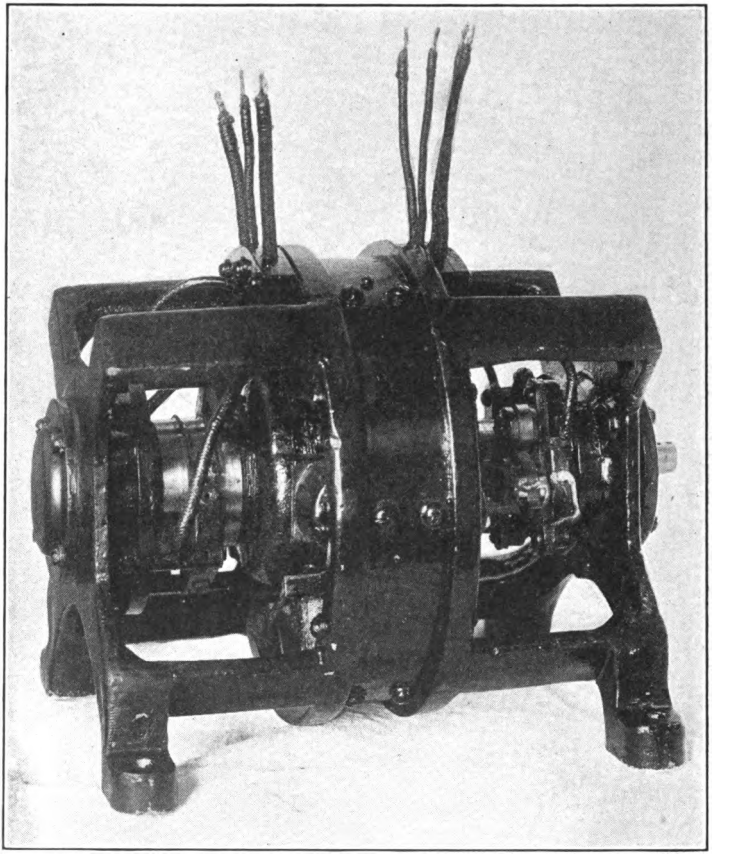

FIG. 14.—COMBINED ELECTRICAL GENERATORS.

course, more sensitive to inclinations of the rudders when running at high speed.

The lateral stabilizer serves as a directive factor, acting on the pilot valve to control the movements of the ailerons so that they ought to operate to counteract against tipping laterally. When

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turning, the lateral stabilizer operates the control mechanism to bank the machine to an angle sufficient to prevent skidding.

The gyros of the aeroplane stabilizer are continuously spun by three-phase alternating current derived from a small generator driven from the shaft of the engine. This generator is designed to develop alternating current for driving the gyros, low-voltage direct current for exciting its own fields, and single phase alternating current for use in connection with the radio set. The low-voltage direct current may also be used for ignition service of the engine.

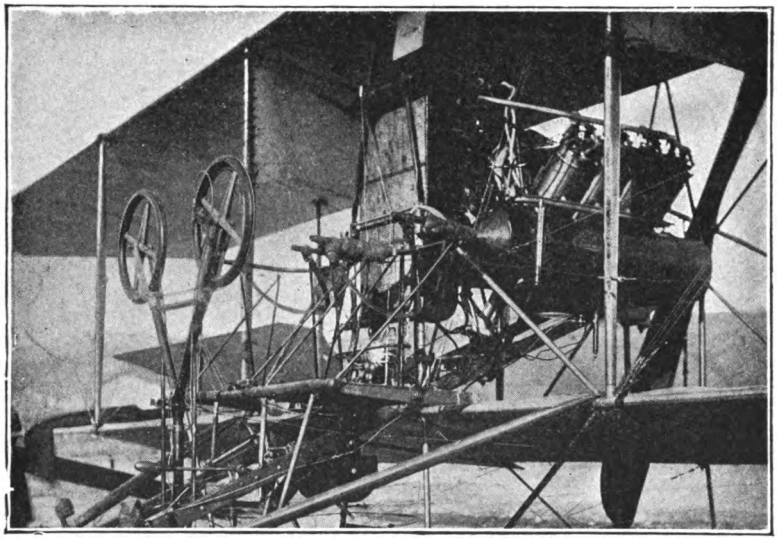

FIG. 15.—SPERRY STABILIZING APPARATUS (LATERAL AND LONGITUDINAL) INSTALLED ON A CURTISS MACHINE.

It is an interesting fact that the gyros connected to the generator circuit act as boosters to restore part of the energy given to them when a circuit to the wireless is closed; thus momentarily the wireless equipment is supplied not only by the generator but also the gyros acting as induction generators.

A valve connected to the compression space of one of the engine cylinders automatically stores compressed gas in a small accumulator tank, from which it is used to operate the pistons controlling the ailerons and rudders.

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The same type of stabilizer may be used on any type of aeroplane, as the installation simply involves supporting it firmly on the machine and attaching the arm operated by the compressed air piston to the wires or levers of the existing hand control. Both ends of the compressed air pistons are provided with valves, all of which may be opened by releasing a thumb button attached to the steering wheel of the aeroplane. When these valves are opened, the stabilizer continues to function, so far as the relation

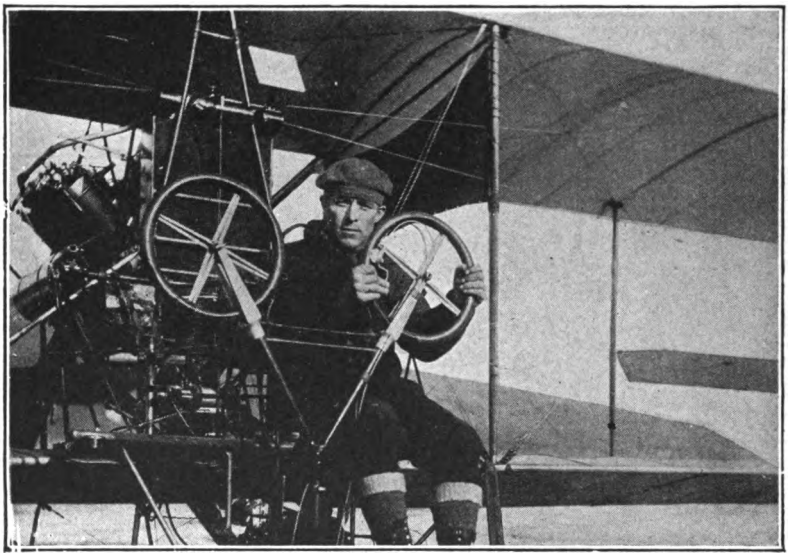

FIG. 16.—THUMB BUTTON ON HAND WHEEL FOR HAND CONTROL.

of all of its parts is concerned, but has no effect on the ailerons or rudders, as the piston is prevented from doing any work. This makes it possible for the aviator to instantly shift from hand control to automatic control.

The weights and dimensions of the various parts of the stabilizer are surprisingly small. The weight of the generator is about 25 pounds and it occupies a space of about 6 by 6 by 10 inches. The lateral stabilizer weighs about 18 pounds and is small enough to be conveniently disposed at the back of the aviator's seat. The longitudinal stabilizer weighs about 17

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pounds and is placed below the aviator's seat in such a position that he can see its operation at all times.

Fig. 12 is a view of the lateral stabilizer. Fig. 13 is a view of the longitudinal stabilizer. Fig. 14 is a view of the combined electrical generator. Fig. 15 shows both stabilizers installed on the Curtiss hydro-aeroplane. Fig. 16 shows the thumb button by means of which the stabilizers may be manually directed.

The automatic control of stability of the heavier-than-air machines will do much to decrease the growing list of fatalities, as it provides a means for acting simultaneously with the disturbing air currents whereas the aviator must always wait until the effect has manifested itself before he applies the remedy and then he very often misjudges the amount by which he should move his controls.

The automatic control of stability will be especially valuable to the military use of the aeroplane, as it will make it possible to fly in almost any condition of weather and will make long flights possible. In reconnoissance service only one man will be necessary, as the machine may be controlled automatically while the aviator makes sketches, records information obtained, or operates the radio set to communicate with his base.

I wish to acknowledge the valuable assistance rendered by Mr. Glenn H. Curtiss, Lieut. Harold Gieger, Chief of the Army Aviation Corps at San Diego, Cal., and last, but not least, the most valuable assistance and encouragement given me by Captain W. Irving Chambers, U. S. Navy, and his brother officers of the Navy Aviation Corps.

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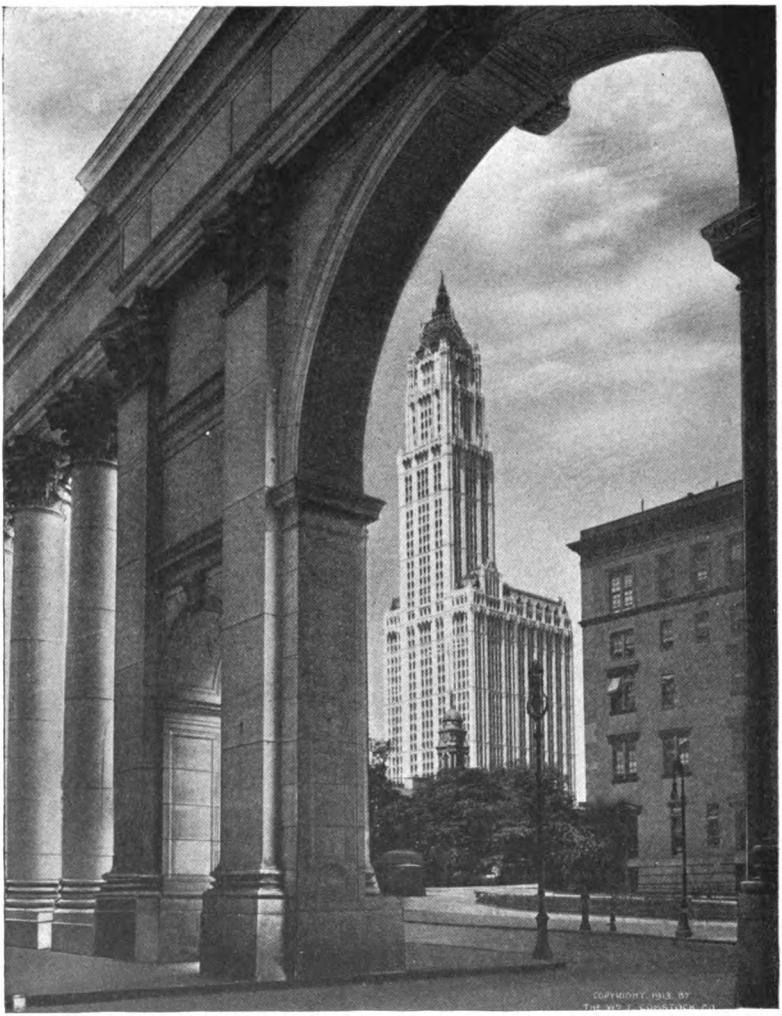

FIG. 1.—VIEW OF THE WOOLWORTH BUILDING FROM MUNICIPAL BUILDING.
(Courtesy of *Architecture and Building.*)

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DESCRIPTION OF THE ELEVATOR EQUIPMENT AND THE ELECTRIC INSTALLATION IN THE WOOLWORTH BUILDING, NEW YORK CITY.*

By Charles E. Knox.

From the engineering point of view, the three big problems involved in the design of a tower building such as the Woolworth structure, are the foundation work, the structural steel work and the elevator equipment. These problems are necessarily quite complex, and on their proper solution largely depends the success of the building as a financial investment. This is particularly true of the elevator equipment, for if the service is not adequate or safe the public soon becomes aware of that fact and renting becomes extremely difficult. There are a number of buildings in New York which are very poor investments, due largely if not entirely to inadequate elevator service, or to interruptions or accidents in the operation of the elevators. This paper will describe some of the more unusual features of the elevator equipment and also the electrical installation in this building.

ELEVATORS.

The problem of selecting the number, arrangement, type and speed of elevator for a building requires a large amount of experience, sound judgment, and careful consideration of the duty and service required of the elevators. At no time in elevator history have there been so many different types of elevators available, and at no time has the evolution of elevator design been so rapid. Furthermore, the demands of the public have constantly become more exacting in regard to speed and service, and the problem has therefore become more difficult to solve. In

* A paper presented at the 319th meeting of the New York Electrical Society, held in the Woolworth Building, New York City, June 12, 1913.

The *Transactions* are indebted to the courtesy of the *Electrical World*, for several engravings used in illustrating this paper.

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the case of the Woolworth Building, owing to the great height of the structure the number of types to choose from of elevators was restricted. The total height of the building from the sidewalk to the top is 770 feet, and the Observation Gallery at the 54th floor is 727 feet above the sidewalk.

There are a total of 28 elevators in the building. Most of the elevators can be run down to the basement, but ordinarily they start at the ground floor. Two of the elevators run to the 51st floor, two to the 46th floor and two to the 41st floor. Fourteen elevators run to the 27th floor and four to the 12th floor. Two additional elevators at the rear of the building which serve for freight and employees, as well as for occupants of the building, run to the 28th floor. The shuttle elevator running from the 51st to the 54th floor, for carrying passengers to the Observation Gallery, was installed because structural conditions would not permit of running the high rise elevators above the 51st floor. A push button type of elevator is provided to run from the bank vault in the basement to the banking rooms on the second and third floors. The structural conditions incident to the tower and the height of the building to a very great extent limited the arrangement and the number of the elevators, any modification of which would have resulted in a serious loss of space and considerable increase in the cost of the building. The great height of the tower excluded the hydraulic type of elevator from serious consideration. Naturally with the height of rise required it was desirable to run the elevators at as high a speed as possible. A recent modification of the Building Department rules permitted express elevators to run at a speed of 700 feet per minute, and this speed was selected for the Woolworth Building.

The elevator selected for this building is known as the gearless "one to one" electric traction type. The general principle of this elevator is extremely simple. In some of the old fashioned wells in the country a device was used for drawing water, similar to that shown in Fig. 2. The outfit consisted of two buckets connected by a rope, the rope passing a number of times around a large wooden spool. This spool was fastened on a shaft, with a crank handle at one end, and by turning the crank, one bucket would be raised, the other, of course, being lowered. The rope

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was passed around the spool a sufficient number of times to prevent the rope from slipping. This was virtually a traction elevator for drawing water. Fig. 3 shows how close is the analogy. In the case of the elevator, the car is attached to one end of the rope, and the counterweight to the other end. Instead of a wooden spool or shaft, the rope passes over a driving sheave at the top of the hatchway, and instead of winding two or three

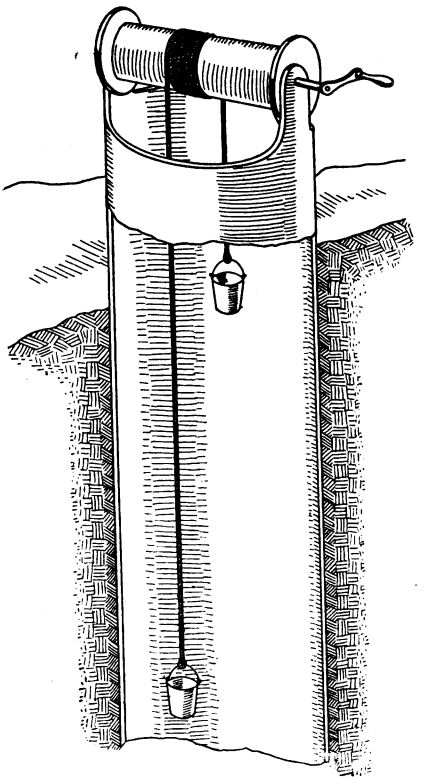

FIG. 2.—DIAGRAM OF OLD FASHIONED WELL, SHOWING PRINCIPLE OF OPERATION OF TRACTION ELEVATOR.

times around the sheave, it is passed around an idler pulley underneath the driving sheave, and thence back over the driving sheave. This gives the necessary tractive force and prevents slipping. In place of the crank handle and the man turning it, we have an electric motor mounted on the same shaft as the

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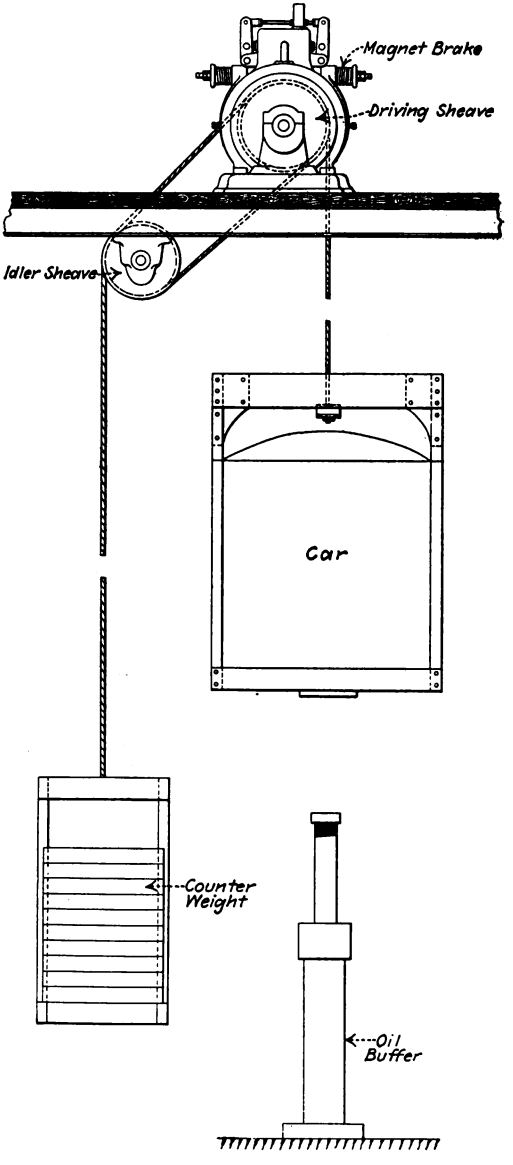

FIG. 3.—DIAGRAM OF TRACTION ELEVATOR.

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driving sheave. When the motor turns the car goes up, and the counterweight goes down, or vice versa.

Fig. 4 shows the elevator machine for a gearless traction elevator. This machine is nearly always placed at the top of the shaft. Even from this brief description it is evident that simplicity is the keynote of the gearless traction type of elevator.

This elevator has a positive safety feature, inherent or peculiar to the method of drive. To return to the analogy of the well, it is obvious that if there were too great a difference in weight between

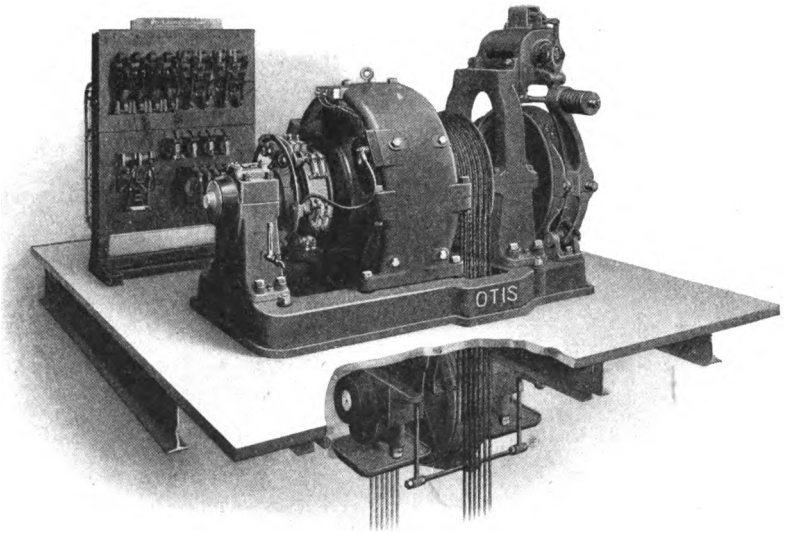

FIG. 4.—MOTOR, SHEAVE, BRAKE, IDLER, ETC., OF TRACTION ELEVATOR.

the empty bucket and the full bucket, and a person continued to turn the crank, the full bucket could not be raised, for the reason that there would not be sufficient adhesion or traction of the rope to lift the load. This same fact holds true in the traction elevator, and provides one of its greatest safety features; for if the counterweight is at the bottom of the shaft and rests on the buffer, even if the motor continues to run, the car cannot be driven into the overhead work, there being too great a difference between the load on the car side and the load on the counterweight side, owing to the load of the counterweight having been removed. Therefore, if for any reason, the car went beyond

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the top landing, and the motor continued in operation, it would be impossible to make the car run further, because the force which raised it had vanished.

To continue with the description of safety features, the device first in importance is that known as the "under car safety," which becomes active should the car for any reason exceed a certain speed. It is operated by means of a flyball governor placed at the top of the hatchway, the balls of which are driven by a sheave, around which the governor rope passes, this rope being attached to a second rope passing around a drum underneath the car. As the elevator car travels the governor rope travels with it, driving the sheave and rotating the balls on the governor at the top of the hatchway. In case the car speed exceeds 800 feet per minute, the balls are raised by centrifugal force to such a point that two jaws are thrown in action and grip the governor rope. The governor rope is now stopped, and as the car proceeds to travel, the drum on the safety plank underneath the car starts to rotate, being driven by the rope passing on its outer grooved surface. The inside of the hub on this drum is threaded, the thread engaging with two shafts, one of which has a right-hand and the other a left-hand screw, and the continued rotation of the drum drives these shafts in an outward direction.

The outer end of each of these shafts is equipped with a wedge which tends to press two very heavy jaws against the guide rails. These wedges are so shaped that at the beginning of the movement of the drum the clearance between the jaws and the guide rails is rapidly taken up, but gradually the movement becomes less. By this means the car is gradually but surely brought to rest. Of course, the action of the governor and the rotation of the drum and the application of the jaws to the rails are entirely automatic, and the action takes place when the car exceeds a speed of 800 feet per minute. Before accepting the elevators that are now installed in the Metropolitan Life Tower, the writer made approximately eighty tests of this particular safety device. The device is very seldom called into operation because a number of electric governing and controlling devices which act automatically tend to prevent the car from overspeeding and thereby avoid the necessity of the governor going into operation.

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The fly ball governor overhead is also equipped with electrical contacts, one of which tends to regulate the speed of the car by automatically controlling the motor speed, while the other contact shuts off the current entirely in case the car speed exceeds a certain limit. Both of these electrical devices operate before the flyballs are thrown out sufficiently to grip the governor rope.

Hydraulic buffers are placed at the bottom of the hatchway which act to bring the car or counterweight to rest in case the car overspeeds or runs below the bottom landing. These buffers will bring the car gradually to rest, even when traveling at a speed of 1,000 feet per minute at the time it strikes the buffer, without injury to the passengers. Of course, this buffer does not operate unless the car goes below the bottom landing, which could only happen when all of the electrical devices which stop the car, simultaneously failed to operate. This buffer is one of the most important safety features, as it prevents the possibility of one of the most frequent causes of elevator accidents. Strange to say, however, it is applied to very few elevators at the present time, very short spring buffers being ordinarily used.

The spring buffers commonly provided are usually eight to twelve inches in length and the stop occasioned by the car being brought to rest on these short springs is frequently sufficient to injure the passenger. You will often read accounts of elevators falling and people being injured, when as a matter of fact the elevator has not fallen, but gone beyond the limit of travel—that is, below the bottom landing—the car striking the short spring buffers, and coming to such an abrupt stop as to injure the passengers ankles or throw them violently to the floor. Accidents of this nature can usually be prevented by providing hydraulic buffers of proper length of stroke, such as are used in this building.

In this building these buffers have a stroke of from four to five feet, which instead of stopping the car in a distance of four to six inches, gradually but quickly bring the car to rest in a distance of about four feet. I have made tests on these buffers at the elevators at the Metropolitan Life Insurance Tower, running the elevator car below the bottom landing (by cutting out the safety devices which ordinarily prevent it from going beyond

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the landing), the car striking the buffers at a speed of 1,000 feet per minute. These tests were made with people in the car, who found that the stops were neither injurious nor even very uncomfortable.

Another of the safety devices provided in this building is that known as the "retarding and latching safety." This device consists of a number of steel wires, strongly secured in position at each side of the upper end of the hatchway. These wires pass between pairs of steel plates, between which plates are placed steel pins, so staggered, or located that the wires between the plates pass around and between the pins in such a manner that the plates cannot be moved without deforming or kinking the wire. To move the plates, therefore, a considerable constant force is required, as the wires are stretched somewhat tightly, and therefore tend to prevent the movement of the plate. A projecting bar or dog is provided at the top of the car which presses against these plates in case the car or counterweight goes above the top landing. If for any reason the other safety devices should fail and the motor continue to run, the car would be quickly brought to rest after it had passed the top landing by the retarding effect of these plates. Latches are also attached to the car, which would rest on the top of these plates in case of over-travel, and therefore prevent the car from dropping back. If, therefore, the car should pass the top landing, not only is the force tending to drive the car removed, as already explained, but the further movement of the car is retarded by this security retarding device.

A powerful brake provided on the elevator machine is actuated by means of two independent powerful springs, which hold the car safely at rest unless current is applied to the motor, in which case electric magnets on the brake pull the brake shoes away, against the pressure of the spring. If for any reason therefore, the current is shut off or fails, these brakes are instantly applied by means of two independent springs and the car is safely held. In addition to the control switch in the car, a small safety switch is provided which is connected by an independent circuit to the controller; when this switch is opened the current is entirely shut off the motor and the brake is immediately applied. The

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control switch in the car is so arranged that if for any reason the operator's hand is removed from the handle, the switch immediately returns automatically to the central position and the current is shut off.

An emergency lever is provided in the car which the operator can use to apply the jaws under the car against the guide rails, independently of the automatic governor overhead. The operator can, by working this lever back and forth three or four times, apply the under car safety and bring the car to rest.

At the bottom and top of the hatchway a series of limit switches are provided which first tend to reduce the amount of current and thereby slow down the car, and finally shut off the current entirely and bring it to rest.

Considering that more people are carried vertically in elevators in the City of Greater New York, than are carried horizontally on all of the subway, elevated and trolley lines, the number of accidents is extremely small. A very large percentage of accidents in elevators is caused by people falling down the hatchway. To avoid this type of accident I specified a contact switch to be placed on the hatchway doors and so connected that the car cannot be started until the door is practically closed. You have doubtless noticed when getting on or off an elevator car that the operator will often start the car before the door is closed, and sometimes before you are entirely off the car. I have frequently seen operators start the car and be three or four feet away from the floor landing, before the door is even partially closed. As the result of this a great number of accidents occur yearly, which can be avoided by providing means to prevent the car from leaving the floor until the door is entirely closed, or within three or four inches of being closed. In my opinion this device should be provided on all the doors of every elevator hatchway. While it is true that it does retard the average speed slightly, nevertheless the element of safety is far more important than that of speed. Furthermore, by properly designing the doors and hangers, and particularly if the device is so arranged that the car may start when the door is within three or four inches of being closed, the reduction in speed is not important. When the device is so arranged that the car may start before the door

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is entirely closed, a ratchet device is provided so as to prevent the hatchway door from being opened from the corridor side.

From the above description it will be seen that the greatest precaution has been taken to safeguard the passengers in the Woolworth Building. Nevertheless, Mr. Woolworth insisted on going even further and air cushions have been provided for the purpose of bringing the car to rest gradually, in case the other features did not work properly. This air cushion consists of an enclosure wall of concrete and steel placed around each of the cars for a distance of approximately one-fifth of the total rise of the elevator.

The theory of the air cushion is that by enclosing the space at the bottom of the hatchway the air below the car would be gradually compressed in case the car should fall, and thereby provide a cushion of air which would gradually but quickly retard the elevator before the bottom was reached—the car sinking to rest at the bottom of the hatchway.

DISPATCHER'S SYSTEM.

When I first began to study the problem of the elevators in the Woolworth Building, I was convinced that the severe service, the arrangement, and the variation in the rise of the elevators, required a departure from the usual method of starting the cars from the ground floor. In order to expedite the service and to maintain as uniform a schedule as possible, the writer designed a special dispatching system which is used in this building for the first time. The usual method of controlling the elevators is to place at the ground floor a starter who signals the operator and starts each car on its trip. Ordinarily this starter has no further control over the car until it reaches the ground floor again. In some cases in the past the writer made telephone connection to the various cars, sometimes from the starter's position at the ground floor, and sometimes from the engine room, and also used lamp annunciators showing the position of the cars. None of these systems went far enough, and in the Woolworth Building the starting and signaling of the cars will be entirely in the hands of a dispatcher instead of a starter.

The dispatcher's system is located on the second floor over-

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looking the main group of elevators (see Fig. 5). Near the dispatcher's desk is placed a lamp indicator, each lamp corresponding to one floor for each of the elevators within its limits of travel. As an elevator passes a floor a lamp on the indicator is momentarily lighted, corresponding to that particular elevator and the floor passed. By glancing at this indicator the dispatcher knows immediately the location of each elevator. He also knows when an elevator stops at any given floor and for what length of time.

FIG. 5.—DISPATCHER'S STATION FOR ELEVATOR SIGNAL SYSTEM.

Furthermore, the indicator shows him whether the elevators are keeping in proper step, that is, whether they are the proper distance apart and maintaining their predetermined schedule. In case an elevator gets behind the schedule, he can send a signal to the operator to skip a certain number of floors and thereby "catch up" to his schedule.

On the dispatcher's desk are also mounted a number of double-push button switches which the dispatcher uses to cut out or

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transfer the signal on any car, so that when an operator falls behind his schedule he would not receive a signal to stop, and it would be transferred to the next car. For the purposes of signaling, the dispatcher has located on his desk a push-button connecting with a buzzer in each car, and also a telephone switchboard connecting with megaphones in the car, by means of which he may communicate orders to the operators, in addition to the code of signals used by means of the push-button and buzzer. The operator can hear the dispatcher's orders by means of the megaphone without holding a receiver to his ear. In case of necessity the operator in the car may also communicate (by means of a separate telephone) with the dispatcher, but ordinarily it is intended that he should receive orders only and not use the telephone.

Ordinarily when a car drops behind its schedule it retards all of the other cars following, because they lag behind in order to have the first car reach the ground floor ahead of them. In other words, the system usually employed tends to retard the entire service. With the system used in the Woolworth Building, if a car falls behind it is forced to catch up with the schedule by the dispatcher directing it to proceed to the ground floor, thereby distributing the passengers among the cars following. In this way the operators are forced to use every effort to have the cars maintain the predetermined schedule, instead of permitting them to lag behind. It is a matter of common observation that an operator will frequently stop his car at a floor and wait until the car preceding gets ahead of him by four or five floors. By unnecessarily stopping in this manner, additional electrical energy is consumed and the number of cars leaving the ground floor in a given time is decreased, the elevator service being therefore correspondingly reduced.

Near the dispatcher's desk is also placed an automatic starting device which sends a signal to all of the cars at both the bottom and top of the hatchway. This timing device can be arranged so as to send a signal every twenty seconds, thirty seconds, or at any other interval desired. The dispatcher may also cut this timing device out of service for any particular car or group of cars and send the signal himself. A system of signals has

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also been provided for use at night for two of the high rise elevators.

The above dispatcher's system has been worked out very completely, and it is believed will increase the efficiency of the elevator service very materially and will bring about a marked change in the method of operation of elevators in tall office buildings.

ELECTRICAL GENERATING PLANT.

The current supply for the building is derived from a generating plant located in the sub-basement. The total capacity of the plant is 1,500 kilowatts, consisting of two 500-kilowatt units, one 300-kilowatt, and one 200-kilowatt units. Fig. 6 shows the electrical generating plant.

Engines.

The engines, of the Providence Engineering Works manufacture, are all of the tandem compound, non-condensing type, having releasing Corliss valve gear. The engines are designed to operate at an initial steam pressure of 150 pounds, with practically no back pressure, and run at 100 r. p. m. The dimensions of the engine cylinders are as follows:

500 killowatt, 20 in. × 32 in. × 48 in.
300 killowatt, 18 in. × 28 in. × 48 in.
200 killowatt, 14 in. × 22 in. × 42 in.

All the steam exhaust piping for the engines is carried in a pipe space or cellar beneath the engine room floor, the valves being operated by wheels located on floor stands placed adjacent to the corresponding engine in each case.

An automatic system of lubrication has been provided for oiling the various parts of the engines. This system consists of pipes running to the various devices to be oiled, and includes oil reservoirs, filters and pumps for circulating and filtering the oil.

Generators.

The generators are of the two-wire compound type; wound for a potential of 250 volts, being compounded from 246 volts at no load to 250 volts at full load. The compounding of the generators, as well as the regulation of the engines, is exceptionally good.

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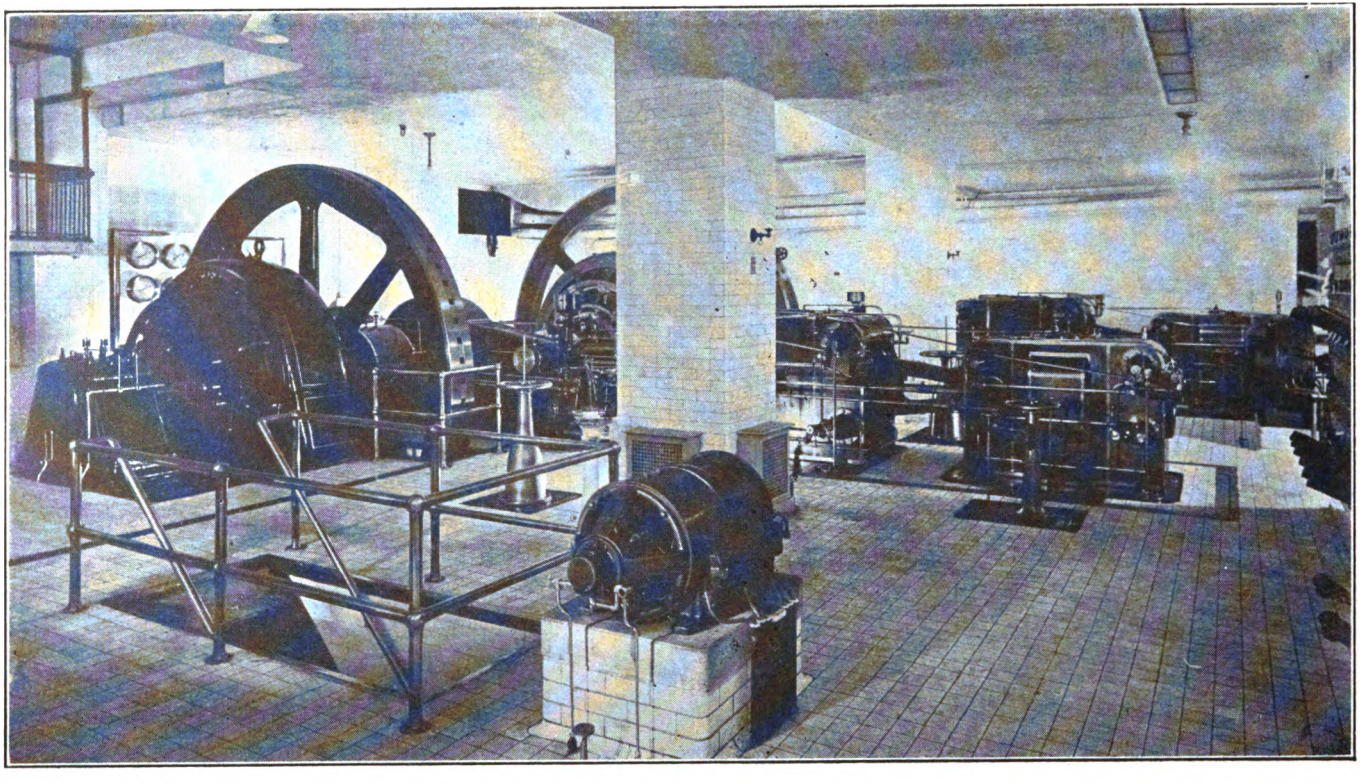

FIG. 6.—ELECTRIC GENERATING PLANT.

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Three balancer sets have been provided for the purpose of obtaining a three-wire, 125-250 volt system of wiring. Each of two of these balancer sets has a total unbalance capacity of 30

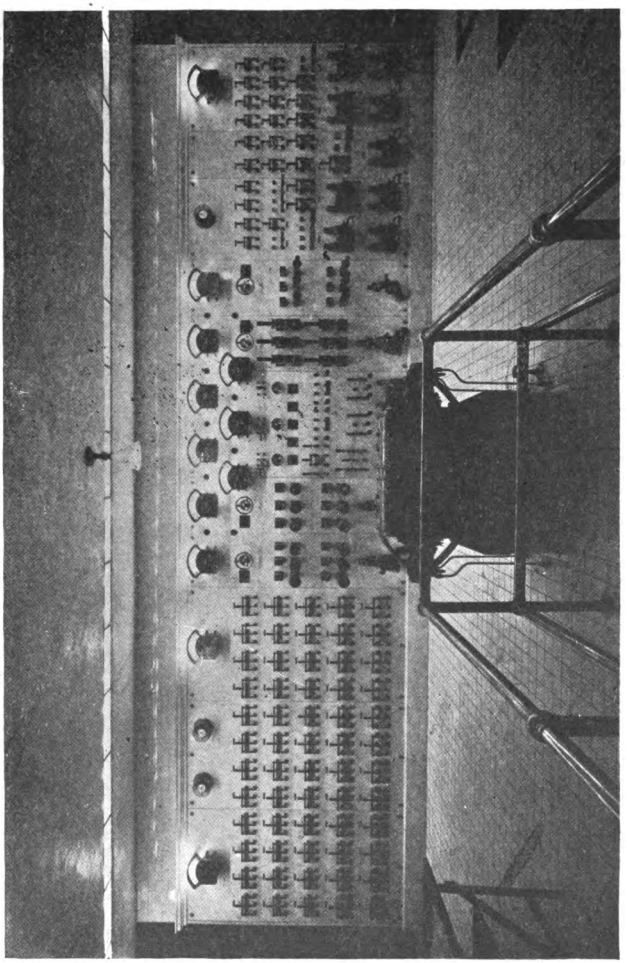

FIG. 7.—FRONT VIEW OF SWITCHBOARD.

kilowatts, the third set having a total unbalance capacity of 10 kilowatts. The generators have an overload capacity of 25 per cent. for an indefinite period, and an overload capacity of 50

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per cent. for twenty minutes. The generators, balancer sets and switchboard are of General Electric manufacture.

Switchboard.

Figs. Nos. 7 and 8 show respectively a front and rear view of the main switchboard. The central panel is equipped with the

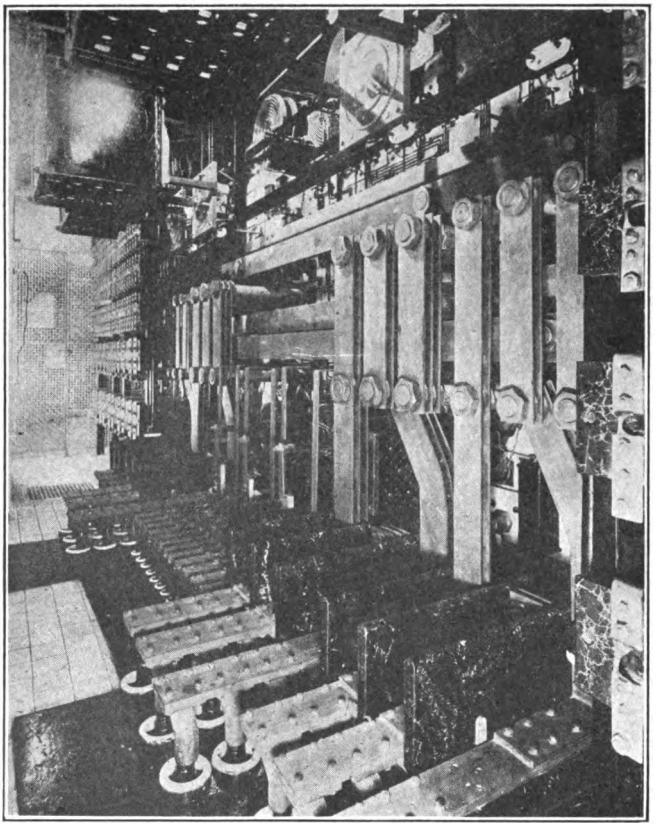

FIG. 8.—REAR VIEW OF SWITCHBOARD.

various controlling and protecting devices for the balancer sets. The two panels on each side of the central panel serve for the generators. The right hand panels are equipped with the switches and circuit-breakers for controlling the various motor feeders,

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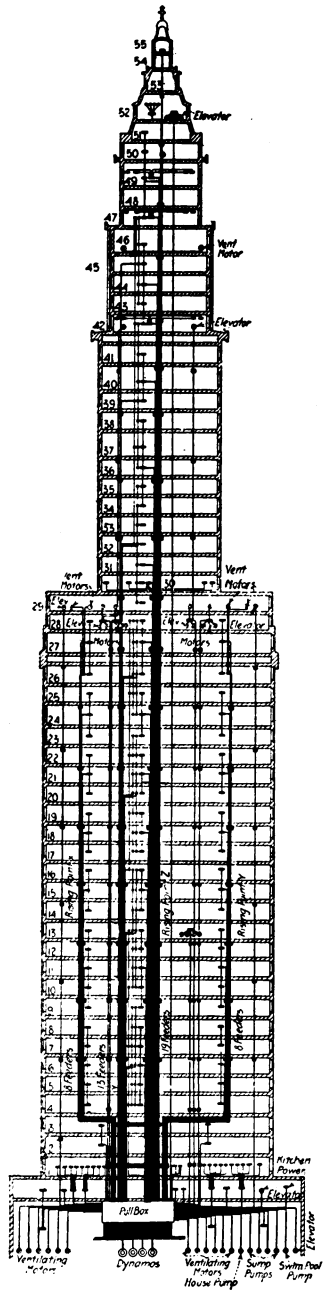

FIG. 9.—ARRANGEMENTS OF FEEDERS AND MAINS AND DISTRIBUTING CENTERS.

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and the left hand panels are equipped with the knife switches for the lighting feeders.

The fuses for both the generators and all of the feeders are placed on special panels back of the switchboard. These fuse panels are arranged so as to make them readily accessible, the feeder fuse panels being placed vertically and the generator fuse panels horizontally. Barriers are provided on the generator fuse panels to obviate the possibility, in case a fuse should blow, of jumping across to the opposite polarity. The two cuts show clearly the various features of the switchboard without further explanation.

WIRING.

Fig. 9 shows diagrammatically the arrangement of the electric lighting and power feeders. Fig. 10 shows a wiring plan of a typical floor indicating the centers of distribution and the general arrangement and connections of the circuits. There are a total of 59 lighting feeders, 39 power feeders, 171 lighting mains and 43 power mains and motor circuits, and 262 cutout panels, forming 175 centers of distribution. Both the feeder and branch circuit conductors are run in iron conduit. For the branch circuit conductors rubber insulated wire is used throughout, but the feeder conductors have special paper insulated wire and the dynamo leads consist of lead sheathed paper insulated wires. Of course, owing to the extremely high rise of some of the feeders, special means of support had to be provided for relieving the strain on the conductors. Special clamps are used to take the vertical strain, these clamps being placed not over 40 feet apart. The longest feeder runs from the switchboard to a panel on the 57th floor, a total distance of 1,000 feet, the vertical rise being approximately 740 feet.

Tungsten lamps of various sizes from 25 to 60 watts, are used for lighting. There are a total of approximately 12,000 outlets and the aggregate installed lighting load is in the neighborhood of 450 kilowatts. The aggregate installed power load, including the elevator motors, is over 1,400 kilowatts.

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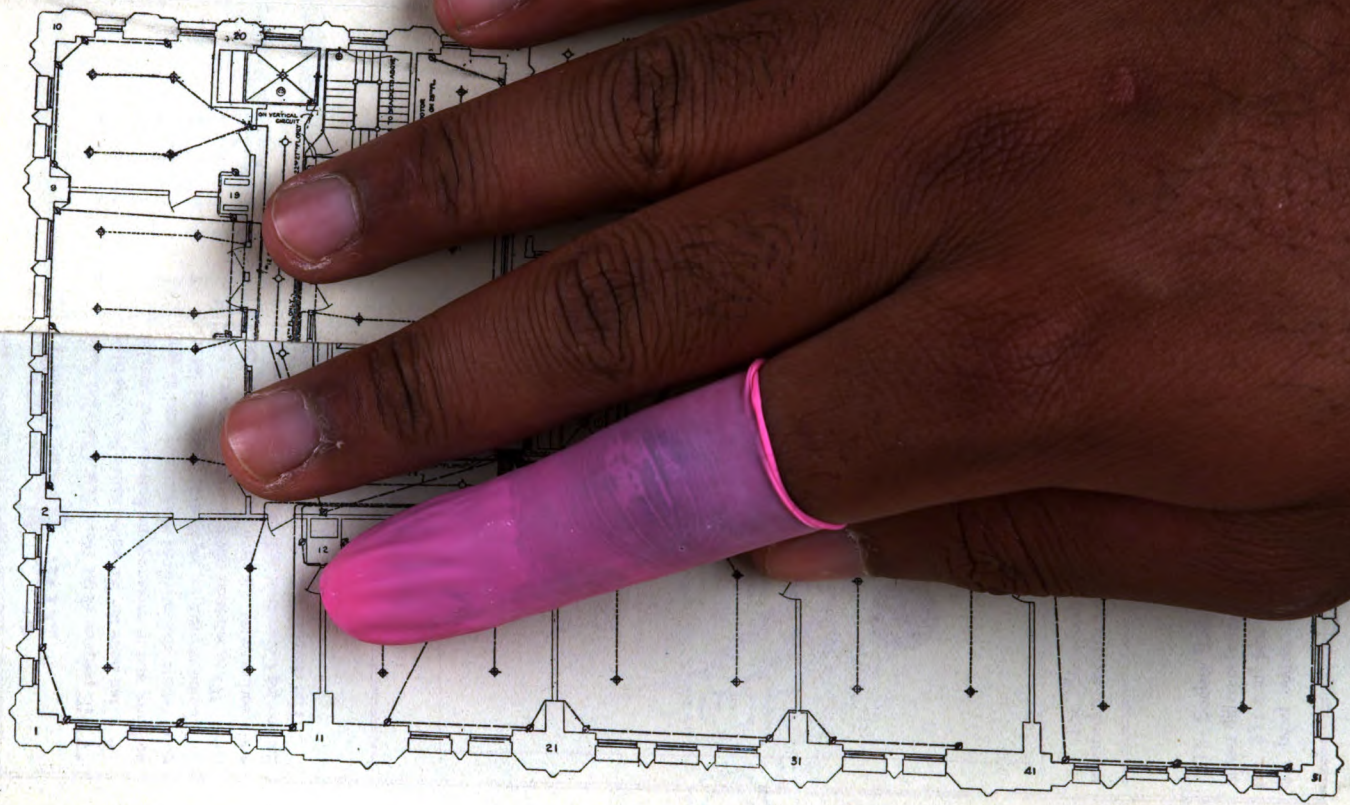

Fig. 10.

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New York Electrical Society

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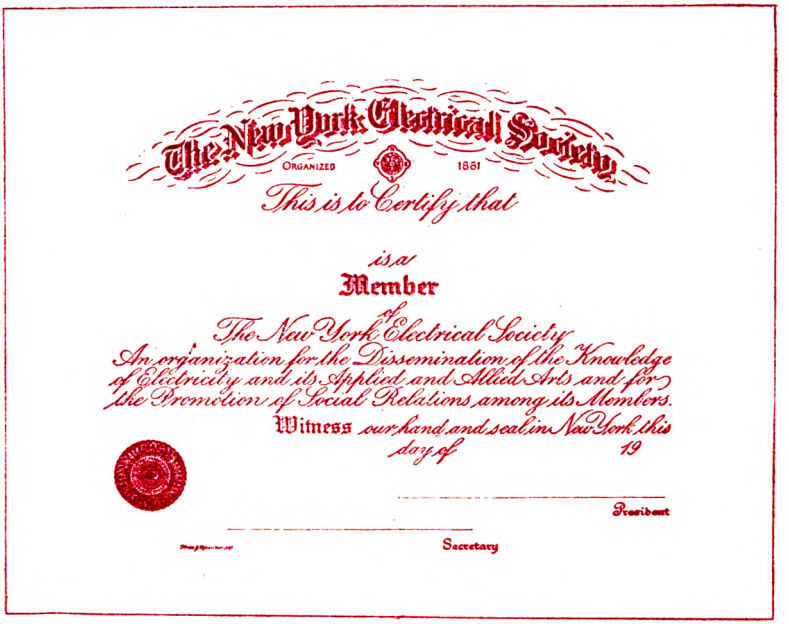
Upon request, an application blank and list of members will be forwarded by the Secretary. When returned filled in with the name, address and occupation of the applicant, and with endorsement by two members of the Society, the application, upon approval by the Examining Committee, will be presented for action at one of the regular meetings of the Society.

The entrance fee is $1.00, and the annual dues, $3.00.

GEORGE H. GUY, Secretary,
Engineering Societies Building, 29 West 39th Street, New York.

Membership Certificate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The New York Electrical Society
An organization for the Dissemination of the Knowledge of Electricity and its Applied and Allied Arts and for the Promotion of Social Relations among its Members.
Witness our hand and seal in New York this
day of 19
President
Secretary

The Membership Certificate of the Society (12 by 15 inches, printed on plate paper) is supplied to members upon application, for a fee, including cost of engrossing name, of $1.00.

Society Badge

The Society Badge can be supplied in four different forms, as follows: Vest pin, $3; scarf pin, $3; watch chain, $3; lapel button, $4. All patterns

are in 14-karat gold and blue enamel and finely finished. The number of the badge and name of owner are engraved on the back without charge.

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